SUPERMARINE SPITFIRE

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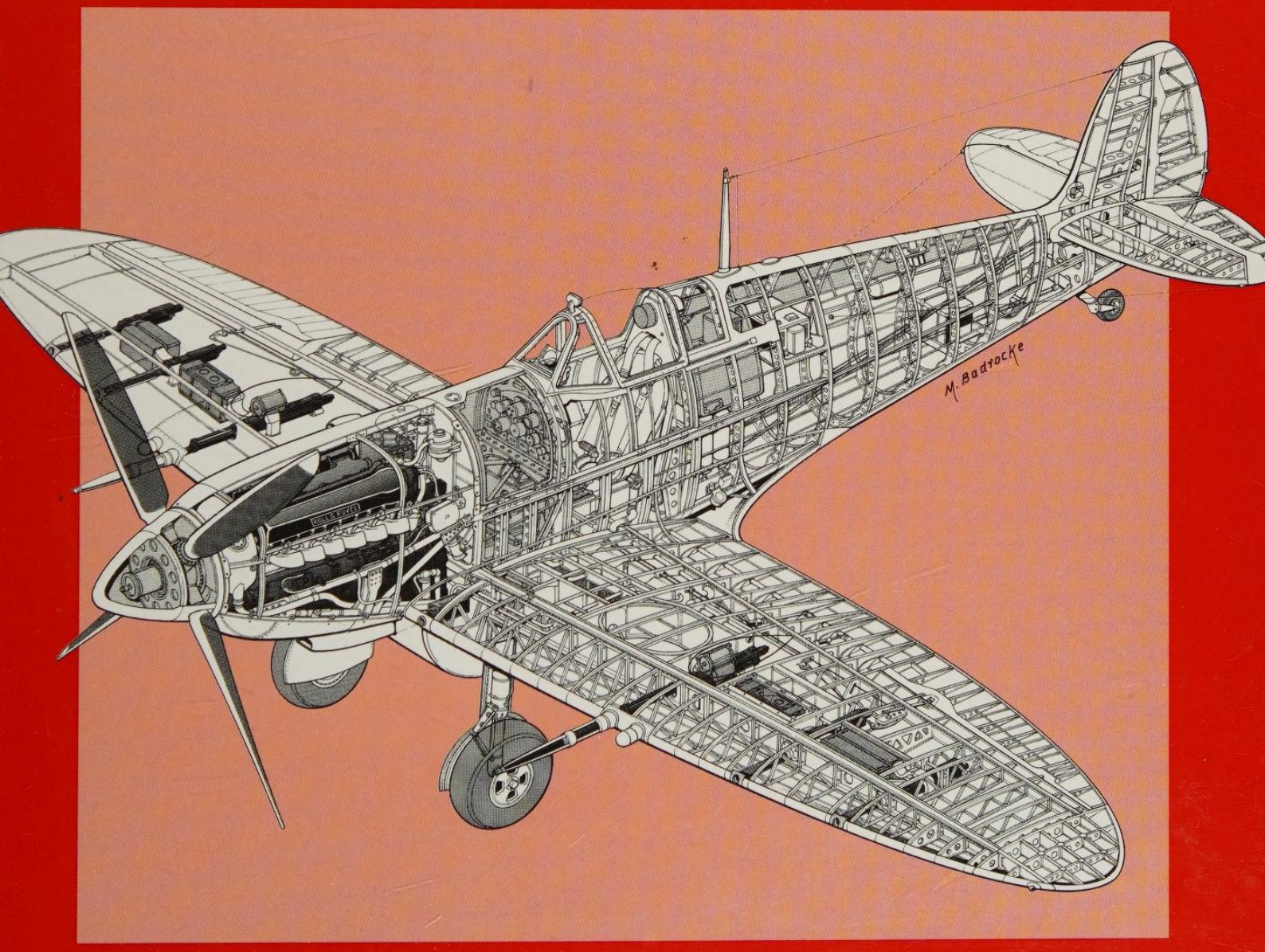
ROYAL AIR FORCE Battle of Britain Memorial Flight
OFFICIAL PRODUCT

1936 onwards (all marks)

Owners' Workshop Manual



An insight into owning, restoring, servicing and flying Britain's legendary World War II fighter

SUPERMARINE SPITFIRE

1936 onwards (all marks)

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Alfred Price and Paul Blackah have asserted their right to be identified as the authors of this work

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WARNING
While every attempt has been made throughout this book to emphasise the safety aspects of working on, restoring and flying Spitfires, the authors and publishers accept no liability whatsoever for any damage, injury or loss resulting from the use of this book.

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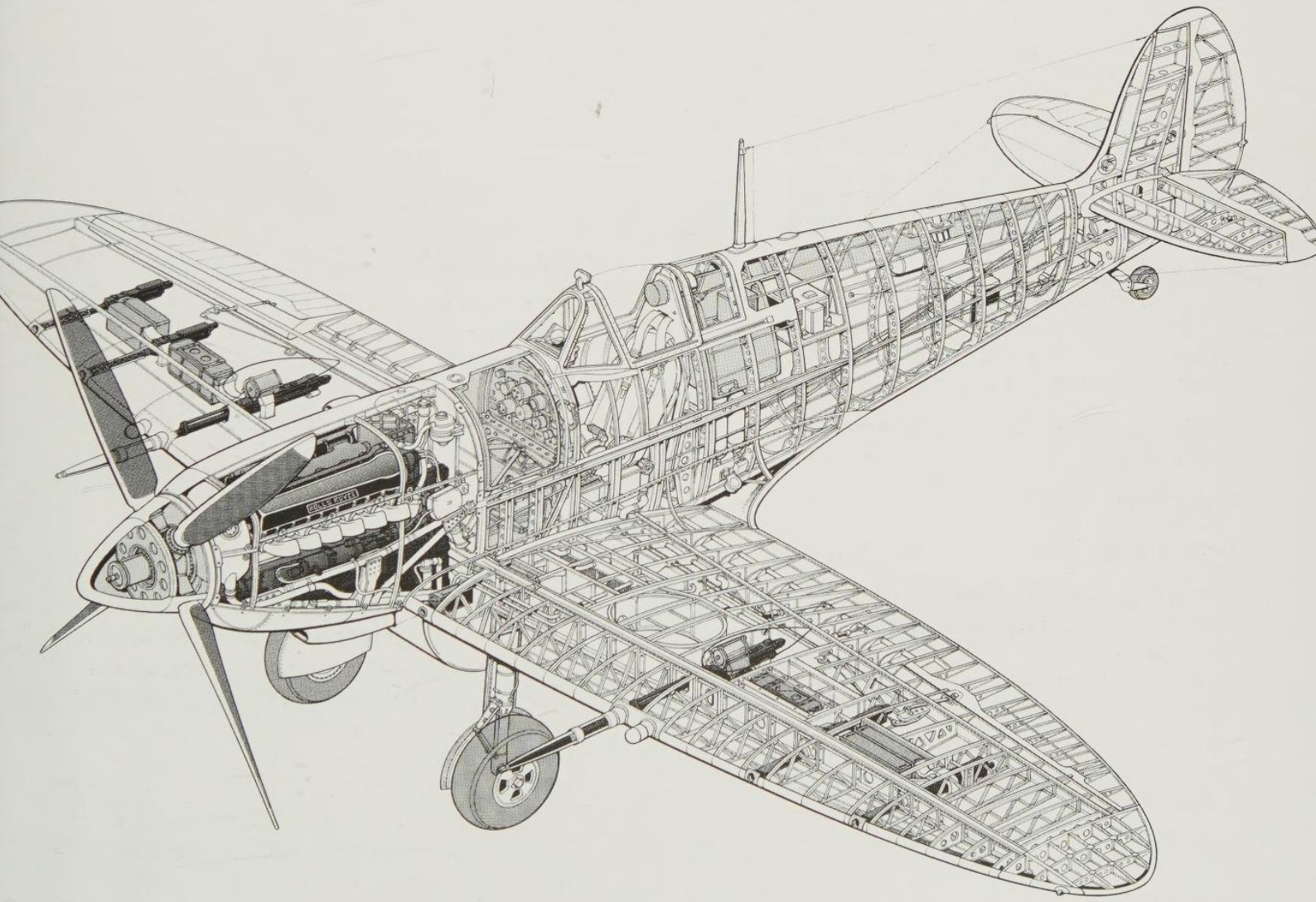

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Dr Alfred Price and Paul Blackah

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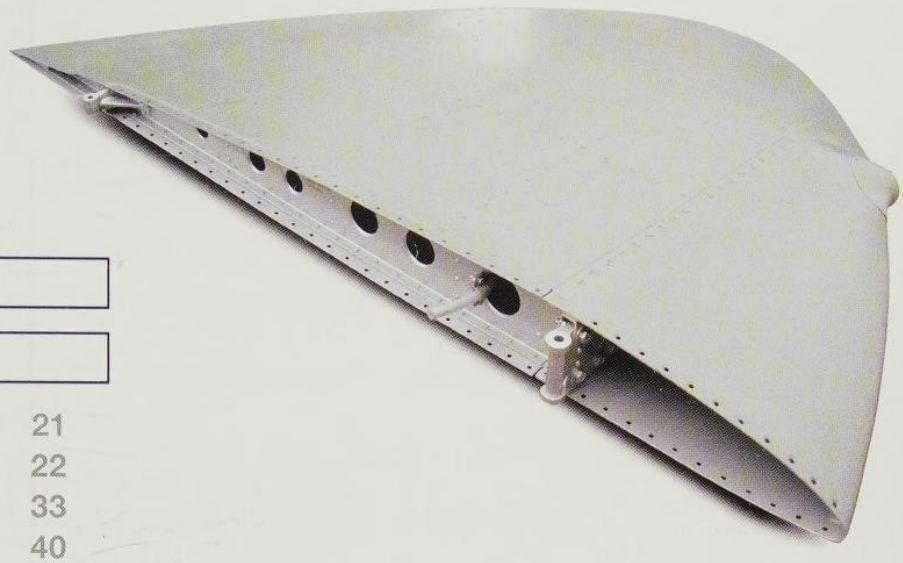

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'I know I fell in love with her the moment I was introduced that summer day in 1938. I was captivated by her sheer beauty; she was slimly built with a beautifully proportioned body and graceful curves just where they should be.'

The Rt. Hon. The Lord Balfour of Inchrye PC, MC,
Under Secretary of State for Air, 1938–1944

(Photo: Neil Bridges)

Introduction

The Spitfire is more than just an aeroplane. It is an icon. It is, moreover, an icon that is quintessentially, indubitably and self-confidently British.

Few British people will dispute the assertion that the Supermarine Spitfire was the most famous aircraft ever to serve with the Royal Air Force. Yet it is pertinent to ask why the Spitfire should have attained its iconic status, to the point where it overshadowed other aircraft types whose achievements were scarcely less significant.

BELOW: Reginald Mitchell led the design team which produced the Spitfire. After the prototype flew he suffered from steadily worsening health, and he died of cancer in June 1937 at the tragically young age of 42. *(Alfred Price Collection)*

Undoubtedly the Spitfire performed brilliantly in the task for which it was designed, that of home defence fighter. Reginald Mitchell's original design was sound to the point of brilliance. Following Mitchell's tragic and untimely death in 1937, at the age of 42, Joe Smith took over the leadership of the Supermarine design team. He assumed the task of exploiting the fighter's huge potential. It reflects the greatest credit on Smith and his team of engineers that they were able to incorporate the raft of far-reaching improvements without ever disrupting the flow of production.

The resultant fighter remained in production for 12 years, which included the technically most innovatory war in history. It was a period that ran from the biplane era to well into the jet age. No other airframe design, ever, was so continuously, so aggressively, so thoroughly and so successfully developed as the Spitfire. Driving that successful development, in both the metaphorical and the literal senses of the word, was the successive increases in power that Rolls-Royce engineers managed to wring out of their magnificent Merlin and Griffon engines.

The effects of these processes were far reaching. At the end of its development life the Spitfire carried an engine that developed more than twice the power of the original. Its maximum take-off weight was more than doubled, its firepower increased by a factor of five, its maximum speed increased by a quarter, and its rate of climb almost doubled.

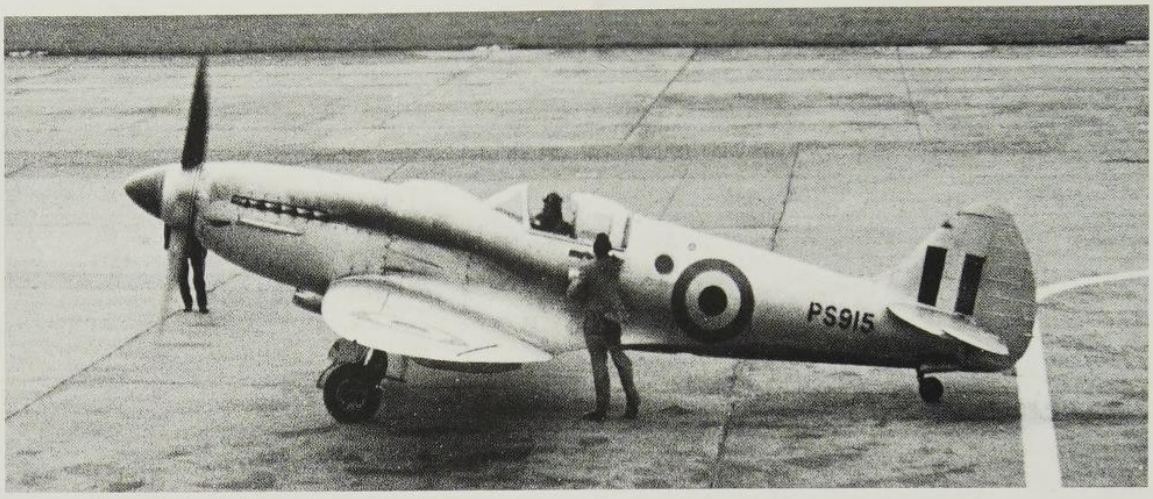
When production finally ended in January 1949, more than 22,000 Spitfires and Seafires had rolled off the production lines. Spitfires were widely exported: more than a thousand were delivered to the Soviet Air Force and a similar number served with the US Army Air Force.

Chance, pure and simple, played an important part in establishing the Spitfire's reputation. How many other fighter types has the Royal Air Force possessed which had world class performance, but which never saw action? Because there was no war, their service demise passed largely unnoticed by the man in the street. Had there been no World War Two, the Spitfire would probably have been just another shapely little fighter to perform aerobatic displays before delighted crowds at air shows.

The Spitfire achieved prominence not only because of its capabilities, but because it was available at exactly the time when Britain's needs – both defensive and morale – were at their greatest. There were other aircraft about which those things could also have been said, but they never attained the glamour of the Spitfire. In truth, the Spitfire achieved its iconic status because it touched the heart of the nation. During the grim summer and autumn of 1940 it was the symbol of defiance, then victory, at a time when Great Britain stood alone and defeat was a menacing possibility. And the collective memory of the nation never forgot it.

ABOVE: Mark II P7350 is the oldest surviving airworthy Spitfire, having been delivered to the RAF in September 1940. During the Battle of Britain it flew initially with No 266 Squadron, whose UO code letters it bore when this photo was taken. The aircraft currently flies with the Battle of Britain Memorial Flight. *(Crown Copyright)*

BELOW: Spitfire Mark I AR213, flown by Tony Bianchi. It is undergoing major refurbishment at Booker and at the time of writing is near airworthy. *(Peter March)*



RIGHT: PS915, a Spitfire XIX of the Meteorological Flight based at Woodvale in Lancashire, was one of the last Spitfires to fly in regular RAF service. It flew with the unit until it disbanded in June 1957, then passed on to the RAF's newly formed Historic Aircraft Flight based at Biggin Hill. At the time of writing the aircraft still flies with the Battle of Britain Memorial Flight. *(Alfred Price Collection)*

Fast forward to June 1957 when the last regular RAF unit to operate Spitfires, the Meteorological Flight based at Woodvale in Lancashire, re-equipped with Mosquitos. On the following day three of the unit's Spitfire XIXs flew to Biggin Hill to join the RAF's newly formed Historic Aircraft Flight. The Flight's remit was to maintain these historic aircraft in flying condition for as long as it reasonably could, for commemorative flypasts and demonstrations at air shows.

Meanwhile, the number of airworthy Spitfires around the world had sunk perilously close to zero. The nadir of their fortunes was in the mid-1960s, when only ten were left. The RAF's Historic Aircraft Flight operated two Mark XIXs. The Belgian company COGEA, working under contract to that nation's armed forces, operated four Spitfire IXs to tow banner targets to train anti-aircraft gunners. One Mark IX was retained by the Israeli Air Force, which flew it occasionally. Three more Spitfires had private owners: the British Aircraft Corporation owned a Mark V, John Fairey owned a Mark VIII converted to a two-seater, and the Rolls-Royce Company owned a Mark XIV.

That number of airworthy Spitfires might have continued on its downward trajectory but for the film *The Battle of Britain*, which appeared in 1969. For this, Hamish Mahaddie, a retired RAF Group Captain, was contracted to assemble a collection of aircraft types that had flown in that action. In addition to several ex-Spanish air force Messerschmitt 109 Buchons and Heinkel 111s (all powered by

BELOW: Line up of ten airworthy Spitfires and three Hurricanes at RAF Henlow in April 1968, to take part in the film *The Battle of Britain*. *(Robert Rudhall collection)*

Rolls-Royce Merlin engines!) his contingent of Spitfires comprised a dozen flyable aircraft and seven more that were able to taxi for use in the ground scenes.

The Battle of Britain film was hugely successful, and it left a couple of important legacies that would do much to ensure the Spitfire's survival as a flying machine in the years to come. Firstly, it led to renewed interest in the surviving airworthy Spitfires, to the extent that no self-respecting air show was complete without an appearance from one of them. And secondly, it showed that almost anyone, provided he or she was wealthy enough, could own and perhaps fly a Spitfire.

Those factors kindled interest in the idea of refurbishing Spitfires to restore them to flight. And, importantly, some larger-than-life characters with considerable personal wealth arrived on the scene. These people were prepared to commit the large sums necessary to give substance to their dreams of Spitfire ownership.

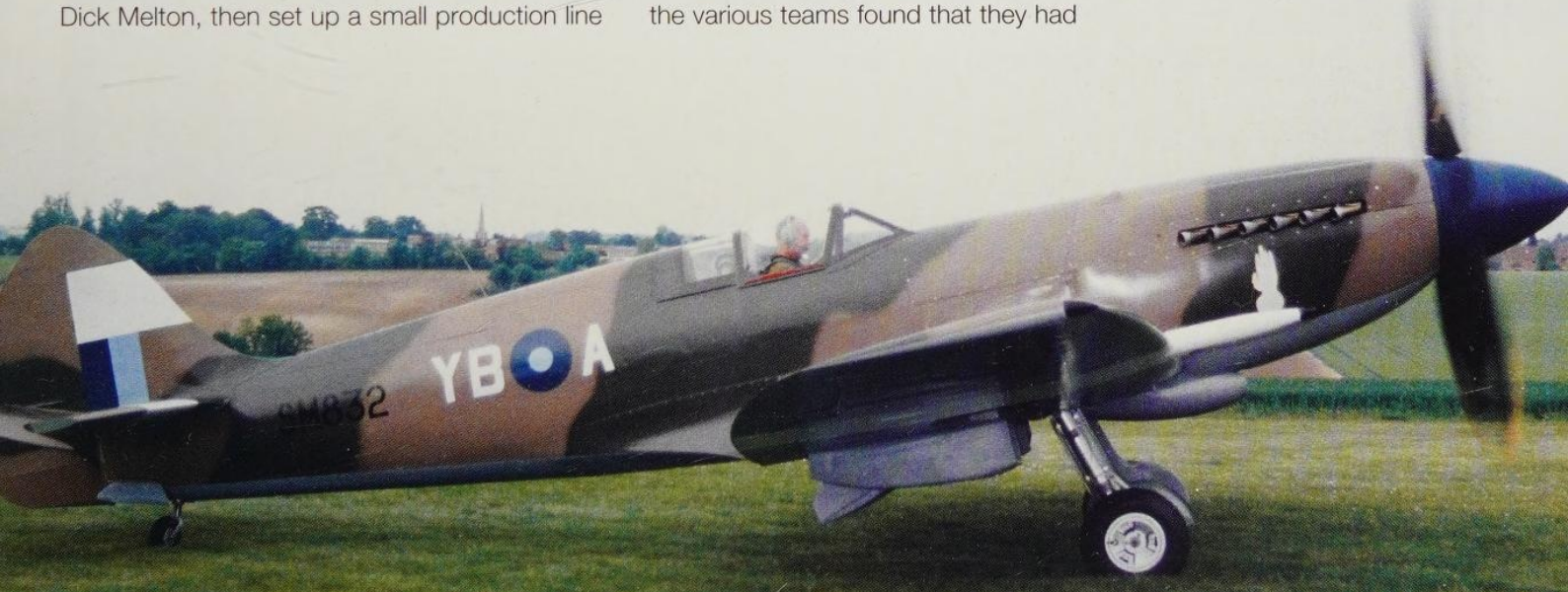
One such man was Doug Arnold, the owner of Blackbushe airport. In 1976 he learned that several Spitfires in a poor condition were sitting at airfields around India. Doug, accompanied by Spitfire historian and collector Peter Arnold (no relation), visited that country and returned having purchased four Spitfires in a dilapidated condition. Doug Arnold and his chief engineer, Dick Melton, then set up a small production line at Blackbushe to restore some of these aircraft to flying condition.

ABOVE: Doug Arnold pictured at the Dehra Dun Military Academy in India in February 1976, with the weather-worn Mark XIV SM832 which he purchased and shipped to England. *(Peter R. Arnold)*

In 1977 the Haydon-Baillie brothers, Ormond and Wensley, also went to India and brought out eight more Spitfires. Eventually 'the Indian connection' would yield 16 of these aircraft, most of which would be restored to flight condition in the years to come.

Meanwhile, Robs Lamplough had conducted a similar search for Spitfires in Israel. There he was able to buy three Spitfire IXs in a poor condition, having spent a couple of decades sat in the open at kibbutz playgrounds. Lamplough kept the best one for himself to refurbish, and sold on the other two.

Having launched these restoration projects, the various teams found that they had



After a protracted restoration lasting for the better part of two decades, SM832 finally took to the air for its first post-restoration flight in May 1995 with John Allison at the controls. The aircraft carries the markings of fighter ace Squadron Leader 'Ginger' Lacy, when he commanded No 17 Squadron in 1945. *(Peter R. Arnold)*

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committed themselves to an enormous amount of work. Several years, in some cases a couple of decades, would elapse before their labours produced Spitfires that could take to the skies.

In 1984 Charles Church, owner of the house building company Charles Church Homes, became another major player on the burgeoning Spitfire restoration scene. His own luxurious home, near Micheldever in rural Hampshire, even boasted a private airstrip large enough to operate a Spitfire. As a hobby, Church began to assemble a collection of Warbird aircraft that would eventually include half a dozen Spitfires as well as a Spanish Messerschmitt 109 Buchon and a non-flying Lancaster bomber.

Importantly for this account, the restoration work on Charles Church's aircraft provided much-needed cash injections to a number of fledgling companies trying to produce Spitfire components on a commercial basis. Charles Church was killed in 1989, after the Spitfire he was flying suffered an engine failure and crashed, but by then most of the aircraft restoration companies he had supported could stand on their own two feet.

During this period around 40 RAF stations at home and overseas displayed Spitfires near their main gates. These so-called gate guardians were eye-catching, but sitting stoically in the wind and the weather for decades on end led to their steady deterioration. There was corrosion of exposed metal surfaces. Windscreens and canopies turned translucent. Exhaust pipes rusted. Tyres rotted. Improvised repairs, largely cosmetic, did little to halt their decline and nothing to reverse it.

In the late 1980s Tim Routsis, owner of Historic Flying Limited (HFL), in conjunction with the RAF Museum, submitted a novel proposal to the Ministry of Defence in London. In return for three of the gate-guardian Spitfires, he offered to supply the RAF Museum with a Bristol Beaufort and a Curtiss Kittyhawk, both in display condition, which had been refurbished in Australia. He also offered to supply the RAF with a number of high-quality, full-scale fibreglass replica Spitfires and Hurricanes, to replace the gate guardians. With their durable weatherproof finish, these 'ultimate Airfix' planes could sit out in the open almost indefinitely without deteriorating. The MoD accepted Routsis's offer. All the remaining gate-guardian Hurricanes and Spitfires were replaced by these replicas and the original aircraft were given to the RAF Museum for future 'trading' to enhance its collection.

In 1991 RW382, a low-backed Mark XVI, became the first Spitfire restored by HFL to resume flying. In the years to come five more ex-gate-guardian Spitfires would pass through the company's workshops. The MoD deal promoted HFL to the major league in Spitfire restorations, but unfortunately it did not remain there. By the end of the 1990s the company had run into financial difficulties. Enter a 'White Knight' in the person of wealthy Belgian industrialist and ardent Spitfire devotee Karel Bos. He bought the company, took over its debts and generally breathed new life into it. He also moved the company into a hangar at Duxford airfield, where it still resides and remains highly active in the aircraft restoration business.

From the mid-1980s to the mid-1990s a trickle of restored Spitfires returned to the air, as the various restoration projects reached fruition. These moves passed an important milestone on 5 May 1996, with a 'Southampton Salutes the Spitfire' flypast to mark the 60th anniversary of the prototype's maiden flight. Thirteen airworthy Spitfires assembled at Eastleigh Airport, scene of that flight, to commemorate the event. Then, led by the noted air display pilot 'Hoof' Proudfoot, they took off and assembled in formation to fly along the Western Shore close to the sites of the old Supermarine factories at Woolston and Itchen. Police estimated that around 80,000 spectators turned out to watch and applaud the spectacle.

The process of putting newly restored Spitfires into the air continued. On 3 May 1998, 16 Spitfires took part in the flypast over Duxford. Just over two years later, during the Duxford air display on 9 and 10 September to commemorate the 60th anniversary of the Battle of Britain, 21 Spitfires flew into the airfield and 20 of them took part in the flypast on each day.

At the time of writing there are more than 40 airworthy Spitfires around the world, and work is well advanced on others set to join them. The success of the grand flypast of Spitfires over Southampton on 5 March 2036, to commemorate the centenary of the maiden flight of the prototype, seems assured.

OPPOSITE TOP:
Rescuing a gate guardian: under an agreement with the Ministry of Defence, a team from Historic Flying Ltd arrived at RAF Church Fenton in May 1989 to collect Mark V BM597.
(Paul Coggan)

OPPOSITE BOTTOM:
Charlie Brown fires up BM597 for flight in September 1997, following a restoration project that had lasted more than eight years.
(Peter R. Arnold)

ABOVE: Line up of 13 restored Spitfires – at the time a record – at Southampton's Eastleigh airport on 5 May 1996. The flypast was to commemorate the 60th anniversary of the maiden flight of the famous fighter. *(C.J. Wallace)*

MAIN PICTURE: A record broken: 16 Spitfires assembled for a formation flypast during the air display at Duxford on 3 May 1998. *(Wojtek Matusiak)*

The Battle of Britain Memorial flight

July 2007 marked the 50th Anniversary of the Battle of Britain Memorial Flight (BBMF) based at RAF Coningsby in Lincolnshire. Originally called the Historic Aircraft Flight, the unit formed at RAF Biggin Hill in July 1957 with a strength of three Spitfire XIXs and a Hurricane. The Flight changed to its current title in 1973, with the arrival of a Lancaster bomber.

Currently the unit has 11 airworthy aircraft on strength. There are five Spitfires (a Mark II, a Mark V, a Mark IX and two Mark XIXs), as well as two Hurricanes, a Lancaster, a Dakota and two Chipmunks. The Chipmunks serve as trainers, to provide BBMF fighter pilots with experience of handling an aircraft fitted with both a piston engine and a tail wheel.

In 2000 the BBMF received the status of a semi-autonomous independent unit in the RAF, with its own command structure and engineering staff. Squadron Leader Al Pinner, the current commander, has an administrative staff of four and an engineering team of 25. To fly the aircraft he can draw on the services of 24 volunteer aircrew, all of whom have current postings to operational flying units in the RAF.

One of the primary tasks of the BBMF is the long-term preservation of its fleet of aircraft, which form part of the nation's heritage. Piston-engined aircraft, with their old style airframes and avionics, have long been out of service in the rest of the RAF. So the unit has to be particularly careful in handling its aircraft, to ensure it can sustain them in use.

There are two sides to this. One is the materials side, to ensure it can obtain the spare parts and reconditioned engines it needs. The other, equally important side is to provide the training and maintenance of the skills necessary for its engineering team. The engineers are all volunteers, but before they arrive at the Flight

BELOW: The BBMF on parade: the Lancaster leads the formation of four Spitfires, with the Flight's two Hurricanes in the outer wing positions. *(Crown Copyright)*

none of them will have had experience of the sort of engineering that is required there. On a modern aircraft much of the maintenance is done by box replacement. When there is a snag the engineer replaces the relevant box for a serviceable one, and sends the faulty item to the appropriate servicing bay for fixing. In the BBMF, in contrast, most routine maintenance work is performed on the unit.

Commanding the engineering team is a warrant officer, and he, his two chief technicians and two corporals are full-time members of the RAF Volunteer Reserve. These reservists are the bedrock of the organisation and they cannot be posted away, thereby ensuring continuity in the rank structure. Two regular sergeants and 18 junior ranks make up the rest of the team.

The BBMF's plan for long-term survival hinges on its ability to conserve its raft of specialised engineering skills. To that end the reservists and the regular sergeants run a high-grade on-the-job training programme for the junior ranks, which takes place on the unit.

The maintenance programme for the vintage aircraft runs to a six- to eight-year cycle for major servicings. And, overall, the long-term planning runs to around 13 years – that is to say, two and a bit cycles – ahead. The programme can be likened to an elongated relay race, in which there is always another aircraft ready to 'take the baton' from one needing to undergo major engineering. And it all fits into the schedule drawn up several years beforehand. The plan calls for the Spitfires on the unit to fly a total of 200 hours each year. Shared between the five aircraft, that comes to an average of about 40 hours per Spitfire per year.

In Al Pinner's view the Flight's broad strategic objects can be summed up in four words: commemorative, ceremonial, promotional, and inspirational. The commemorative and the ceremonial tasks go together. The flight was formed partly to formalise a tradition that had a Spitfire and a Hurricane leading the annual Victory in Europe day flypast. That event is no longer celebrated annually, so the BBMF now leads the flypast over Buckingham Palace to celebrate the Queen's official birthday. Because of the obvious risks, the unit's single-engined aircraft are permitted to overfly central London only to mark major occasions of state.

The commemorative task is also intended to keep people in touch with their history, by remembering those who gave their lives so that we can live in a free country. The unit is frequently asked if it can put on a fly-by (for which there is no charge) for a veterans' event or an RAF squadron reunion. The Flight places great store on such events, even if there are only 30 or 40 people present. If it can fit in a fly-by with a display running somewhere else, it will do so.

The promotional aim of the unit is that of promoting the RAF itself. The intention is to show that modern pilots can fly their aircraft with the same spirit and panache that characterised their forbearers, and maintain their ethos and sense of professionalism. The objective is to promote the image of the RAF, and establish the BBMF's links with the supporting public. Whenever possible the unit's aircraft land at the airfields where they give displays. The unit has its own sales trailer,

BELOW: Squadron Leader Al Pinner, present commander of the BBMF, joined the RAF in 1983. After completing his training he flew various marks of the Harrier in the United Kingdom and Germany, and went on an exchange posting to Canada where he flew CF-18 Hornets. Following three display seasons as a part-time volunteer pilot with the BBMF, he was appointed commander of the unit early in 2006. *(Crown Copyright)*

It's gold standard engineering

BBMF commander Al Pinner relies heavily on his engineering team to maintain and preserve the unit's collection of aircraft that are part of the national heritage. He commented:

'Our engineers work with a passion. They work incredibly hard, a lot longer hours than you'd expect a contractor to do. And they give up three out of five weekends during the spring and summer display period. Often they work irregular hours. If something gets broken, they'll keep going until it's fixed. We hate to miss a sortie once an event has been booked.

'It's gold standard engineering out there. Our engineering practice is the benchmark to which all other historic aircraft operators aspire. That's how we're able to keep the aircraft going more or less indefinitely.'

Airframe fitter Corporal Rachael Warnes checking the undercarriage pintle of the Mark IX. *(P. Blackah/Crown Copyright)*

which it brings to displays. As well as generating useful funds to spend on the unit's aircraft, it serves as a focal point for those wanting to learn about the unit and its aircraft. Members of the public, many of them very knowledgeable about aviation, love to talk with the unit's aircrew and ground crew standing beside their aircraft. Al Pinner is all too well aware that he cannot take the public's continuing support for the Flight for granted. It has to be earned.

The inspirational objective aims to inspire youngsters to consider a career in the RAF. This is an aim that Al relates to personally. He remembers, as a ten-year-old, watching enthralled as aircraft of the BBMF flew past his school in Stamford on their way to and

from displays. He found the sight and sounds of the Lancaster, the Spitfire and the Hurricane very emotive. Later they were a major factor in inspiring him to take up a flying career in the RAF.

During 2006 the BBMF planned for 783 individual aircraft appearances at 410 events, in some cases with as many as three aircraft. An aircraft might perform at five events during a single sortie, perhaps giving one full display and four fly-bys.

If the RAF's modern jets were to perform in the same way as the BBMF, flying at 3,000ft around the country on their way to and from venues, and down to 100ft when they got there, they would no doubt spark off complaints about noise from some members of the public. With the BBMF it is different. Nobody can remember a complaint about its activities. When its planes pass overhead people look up, stop whatever they are doing and go 'Ahhhh'.

The BBMF has three types of display in its Spitfire repertoire: the solo display, the two-ship tail chase display, and the two-ship synchronised display. For a solo display the RAF levies a charge of £500, plus a further £220 for insurance. Multi-aircraft displays cost correspondingly more and, as mentioned above, its fly-bys are free.

The long-term future of the BBMF is secure, so long as there is a public will to keep it going. Al Pinner and his unit are working hard to deserve and retain that support.

BELOW: The 'Spitfire Row' in the BBMF hangar at Coningsby, showing the aircraft dismantled for their annual inspection. *(Alfred Price Collection)*

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'The Spitfire was a thing of beauty to behold, in the air or on the ground, with the graceful lines of its slim fuselage, its elliptical wing and tailplane. It ***looked*** *like a fighter, and it certainly proved to be just that in the fullest meaning of the term. It was an aircraft with a personality all of its own – docile at times, swift and deadly at others – a fighting machine* ***par excellence.***'

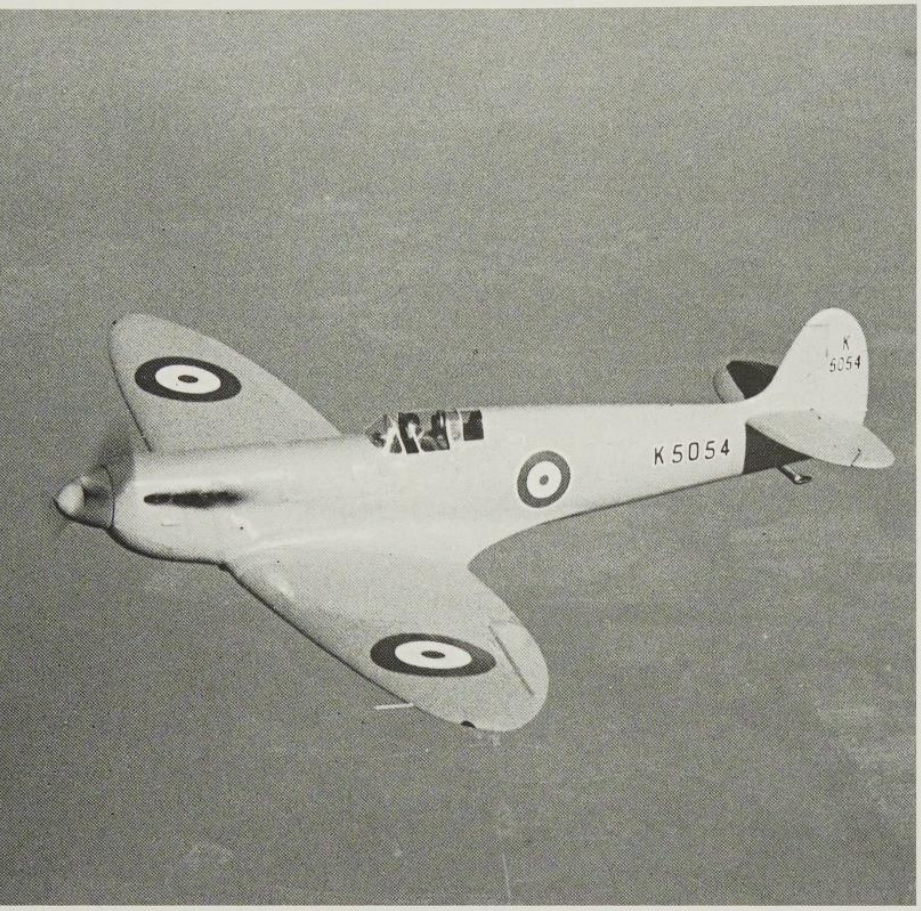
Lieutenant-Colonel William Dunn,
US Air Force, ex-No 71 (Eagle) Squadron RAF

(Photo: Andrea Featherby)

Chapter One

The Spitfire story

Originally the Spitfire was designed solely as a short-range air-defence fighter, but in service its versatility became legendary. Fitted with bomb racks, it became an effective fighter-bomber. With capacious extra fuel tanks built into the wings, the reconnaissance version ranged far and wide over occupied Europe to photograph targets. Renamed the Seafire, a modified version operated from the decks of aircraft carriers. There will never be another aircraft like the Spitfire. Let us hope there will never need to be.



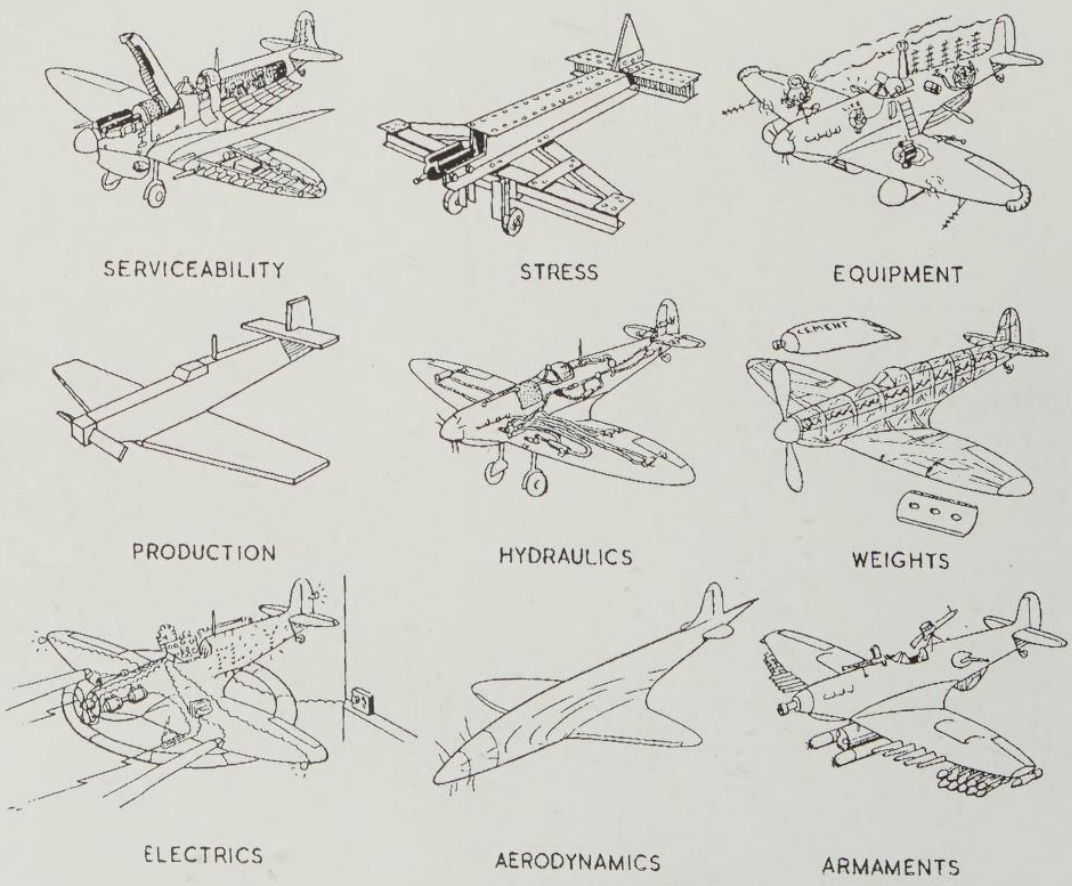
Spitfire: The story of a fighting aircraft

On the afternoon of 5 March 1936 a sleek new fighter plane, bearing the Air Ministry designation F37/34, made its maiden flight from the Supermarine works airfield at Eastleigh (now Southampton Airport). Designer Reginald Mitchell had gained international renown for heading the Supermarine design team which produced the succession of racing seaplanes that won the coveted Schneider Trophy outright for his country. Now he had incorporated his wealth of experience of high-speed flight in the clean-lined new fighter.

Produced at a time when the RAF and most foreign air forces flew fabric-covered biplane fighters with fixed undercarriages and open cockpits, Mitchell's creation was a revelation. The streamlined monoplane was constructed almost entirely of metal, it featured an enclosed cockpit and a retractable undercarriage. Power came from a Rolls-Royce PV XII engine, later named the Merlin, developing 990hp.

ABOVE: K5054, pictured early in its flight-test programme. *(Alfred Price Collection)*

RIGHT: The design of a fighter, like that of any other type of aircraft, is essentially a long list of compromises. Build it stronger than strictly necessary, and it will be too heavy to perform well. Build it too weak, and the structure might collapse the first time the pilot pulls a tight turn. This set of drawings takes a not-too-serious look at the conflicting directions the members of the design team might wish to pull the project. *(Alfred Price Collection)*



Soon after its maiden flight the board of Vickers, Supermarine's parent company, named the aircraft 'Spitfire'. When Reginald Mitchell heard of the choice he expressed his abhorrence in forthright fashion. 'It's the sort of bloody silly name they would give it!' he was heard to comment.

Whatever the merits of its name, the new fighter raised eyebrows wherever it went. At the end of May 1936 the prototype flew to the RAF airfield at Martlesham Heath, for service trials and performance testing. The trials revealed a maximum speed of 349mph at 16,800ft, and the fighter's superb handling characteristics drew praise from service pilots. On the strength of their recommendations, the service placed an immediate order for 310 Spitfires.

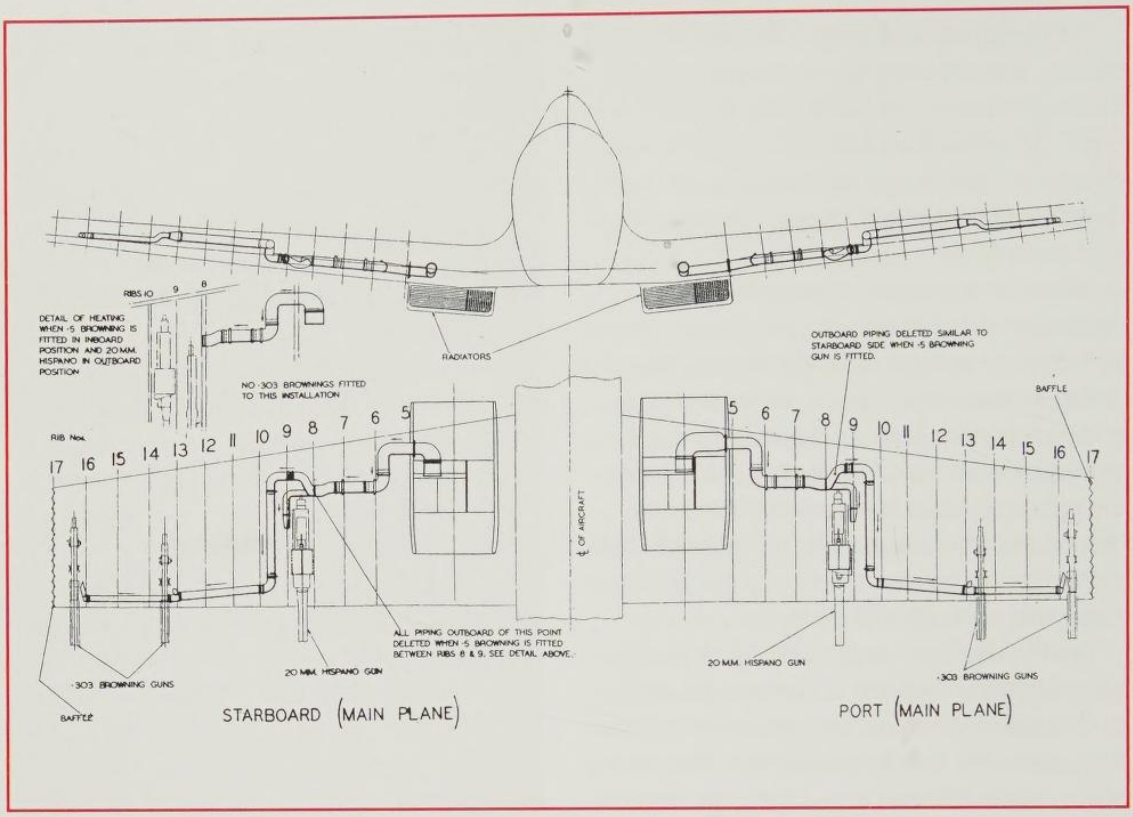
On 11 July Flight Lieutenant (later Air Marshal Sir) Humphrey Edwardes-Jones took the Spitfire to its greatest altitude so far, with a climb lasting 37 minutes that took him to 34,700ft. But there a shock awaited him: suddenly the fighter belched thick white smoke, which trailed a long distance behind it. Edwardes-Jones was horrified, but a thorough check of his instruments left him almost certain that there was no fire. It was the first time he had seen a condensation trail, and when he descended the trail ceased. Nevertheless, Edwardes-Jones had a lot to talk about when he returned to Martlesham.

The test programme of the Spitfire continued, with a continual expansion of the fighter's performance envelope. Early in 1937 there was an important series of tests to prove the functioning of the fighter's armament of eight Browning .303-inch machine guns. When fired at low and medium altitudes over the North Sea, the guns functioned perfectly: each weapon fired its full complement of 300 rounds without incurring a stoppage.

On 10 March an RAF pilot took off for what was intended to be the final weapons test, firing all the guns at 32,000ft. The trial ended in fiasco, however. One gun fired 171 rounds then jammed, one fired eight rounds, and one fired four rounds. The remaining five guns refused to fire at all. That was bad enough, but worse followed. When the Spitfire touched down at Martlesham Heath the shock of the landing released the breech blocks of three guns that had not fired. Each of these

BELOW: Press day at Duxford on 4 May 1939, when No 19 Squadron proudly showed off its brand new Mark I Spitfires. *(Alfred Price Collection)*

RIGHT: A diagram showing the layout and components of the system ducting hot air from the radiators to the gun bays to prevent the weapons from freezing. *(Crown Copyright)*


RIBS 10 9 8
DETAIL OF HEATING WHEN ·5 BROWNING IS FITTED IN INBOARD POSITION AND 20 MM. HISPANO IN OUTBOARD POSITION
RADIATORS
OUTBOARD PIPING DELETED SIMILAR TO STARBOARD SIDE WHEN ·5 BROWNING GUN IS FITTED.
NO ·303 BROWNINGS FITTED TO THIS INSTALLATION
BAFFLE
RIB Nos.
17 16 15 14 13 12 11 10 9 8 7 6 5
5 6 7 8 9 10 11 12 13 14 15 16 17
℄ OF AIRCRAFT
ALL PIPING OUTBOARD OF THIS POINT DELETED WHEN ·5 BROWNING IS FITTED BETWEEN RIBS 8 & 9. SEE DETAIL ABOVE.
·303 BROWNING GUNS
20 MM. HISPANO GUN
20 MM. HISPANO GUN
·303 BROWNING GUNS
BAFFLE
STARBOARD (MAIN PLANE)
PORT (MAIN PLANE)

weapons then loosed off a round in the general direction of Felixstowe!

The cause of the failure was that the guns and ammunition belts froze in the low temperatures met at high altitude. Understandably, RAF leaders were less than happy with this turn of events with the new fighter. At a secret meeting at the Air Ministry the Chief of the Air Staff, Sir Cyril Newall, pungently commented that 'if the guns will not fire at heights at which the Spitfires are likely to encounter enemy bombers, the Spitfires will be useless as fighting aircraft.'

During their attempts to cure the problem of the weapons freezing, Supermarine engineers tried various schemes to duct hot air from the aircraft's radiator into the gun bays. Each new attempt worked a little better than the last, but it was well into 1938 before the problem was finally solved.

In May 1938 the first production Spitfire made its maiden flight. Deliveries to the RAF commenced in July, and in the following month No 19 Squadron at Duxford became the first service unit to re-equip with the new fighter. When World War Two began in September 1939, the RAF had taken delivery of 306 Spitfires and the type equipped ten fighter squadrons. Initially these aircraft were held back for the defence of the homeland.

BELOW: Reconnaissance Spitfire IC, showing the underwing camera door open to remove the precious exposed film magazines. *(Gordon Green)*

A new role

In November 1939 the Spitfire began operating in a new role: that of photographic reconnaissance aircraft. A couple of Spitfires were stripped of guns, ammunition and other non-essential items, and carried aerial cameras in what had been the gun and ammunition bays.

On 18 November Flight Lieutenant 'Shorty' Longbottom flew the first Spitfire reconnaissance mission from the airfield at Seclin in France. For much of the six weeks that followed, cloud cover prevented high altitude photography of enemy territory. Then at the end of December the skies cleared sufficiently to allow the Spitfires to resume their operations. In short order they photographed Aachen, Cologne, Kaiserslautern, Wiesbaden, Mainz and parts of the Ruhr. Significantly, this was done without loss or interference from enemy fighters or AA guns. The flights proved the soundness of the concept of operating the Spitfire in the reconnaissance role, and the unit at Seclin built up to become No 212 Squadron.

On 10 May 1940 German forces launched their powerful *Blitzkrieg* attack on France, Holland and Belgium. During the hectic weeks that followed, No 212 Squadron flew numerous sorties charting the relentless progress of the German Panzer columns through France. The latter quickly reached the English Channel, slicing the defending Allied armies into two.

The Spitfires' regular reconnaissance missions over the battle area, successful though they were, could do nothing to avert the impending defeat. But to cite a much-quoted military adage, 'time spent on reconnaissance is seldom, if ever, wasted'. Thanks to the Spitfires' photographs, the Allied commanders were aware of the enormity of their predicament. That led to a timely start to preparations for the Dunkirk evacuation. It is no exaggeration to say that the photographs played a vital role in ensuring that the Allied defeat in France did not degenerate into an irretrievable disaster.

When the evacuation began, No 212 Squadron withdrew to England and became part of the new Photographic Reconnaissance Unit (PRU).

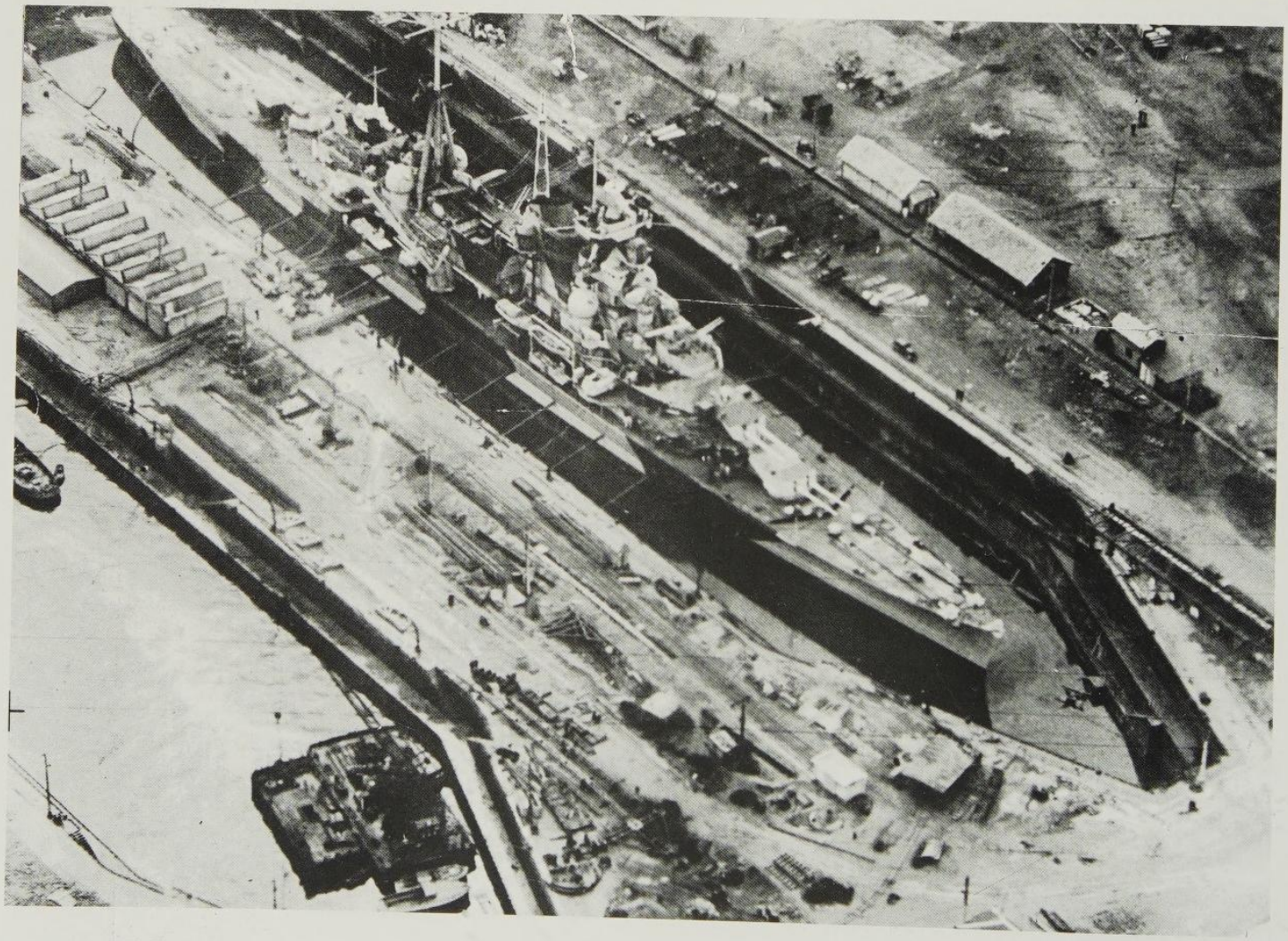
The Battle of Britain

On 1 July 1940, when the Battle of Britain opened, RAF Fighter Command possessed 19 squadrons of Spitfires with 286 aircraft deployed in the front line. In addition, about half that number of Spitfires was held at maintenance units ready for issue to units to replace losses. Thirty-two squadrons of Hurricanes, with 463 aircraft, made up the rest of the modern single-seat fighter force. Of the two British types the Spitfire was the faster by a sizeable margin, and was the only one able to engage the German Messerschmitt 109E on more or less equal terms.

The Battle reached its climax on the afternoon of 15 September, when 114 Dorniers and Heinkels set out to attack the Royal Victoria, the West India and the Surrey Commercial dock areas to the east of London. Escorting the bombers were some 360 Messerschmitt 109 fighters. To meet the incursion Air Vice Marshal Keith Park, commander of No 11 Group of Fighter Command, scrambled all 21 of his Spitfire and Hurricane squadrons. Neighbouring fighter Groups put up seven more squadrons: thus every squadron within fighting range of London was committed to battle, leaving no reserves. The day saw a bravura performance from the RAF's fighter controllers, who brought every one of those squadrons into contact with the raiders. The main battle took place immediately to the east of the capital, and continued all the way to the coast as the bombers withdrew. Twenty-one German bombers, 18 per cent of those committed, where shot down.

The total Luftwaffe loss for the day, taking into account those of fighters and bombers

ABOVE: Spitfire Mark Is of No 65 Squadron pictured shortly after the outbreak of war. The aircraft nearest the camera, FZ-L, was flown by fighter ace-to-be Robert Stanford Tuck. *(RAF Museum/ Charles Brown)*



attacking other targets, came to 56 aircraft. RAF losses that day amounted to eight Spitfires (4 per cent of those committed) and 20 Hurricanes (6 per cent of those committed). The Spitfire's superior performance meant that it was two-thirds less likely to be shot down than a Hurricane, and this ratio was replicated in other major actions in the summer of 1940.

The effect of the German losses that day went far beyond their actual numbers. At their briefings before the action the raiding crews had been told that RAF Fighter Command was on the verge of defeat, down to its last 50 or so fighters. The dash and vigour of Fighter Command's reaction on 15 September demonstrated in no uncertain terms that this analysis was arrant nonsense. The result was an implosion of confidence in the German intelligence picture. Clearly Fighter Command was far from defeated, and certainly that could not be achieved within the strict timescale set for the planned invasion. Accordingly, two days later Adolf Hitler ordered that the invasion be postponed until the following year. The idea would never be resurrected.

The Battle of Britain was the finest hour of RAF Fighter Command, as it was for the Spitfire. German aircrew also played an unwitting part in enhancing the Spitfire's standing, when they habitually reported the fighters attacking them as 'Spitfires', when in reality many were Hurricanes. Thus, as well as drawing plaudits from its friends, Reginald Mitchell's little fighter built up a formidable reputation amongst its enemies.

Throughout the Battle, reconnaissance Spitfires flew daily missions over each of the main ports along the English Channel in northern France, Belgium and Holland. Their photographs provided proof that the German Navy was assembling large numbers of ships and barges for the planned invasion of England. When Hitler ordered the invasion to be 'postponed' after the 15 September action, the vessels began returning to Germany. The Spitfires provided detailed proof of that move also.

In the months to follow, reconnaissance Spitfires were fitted with progressively larger internal fuel tanks, enabling them to range far and wide over Germany and occupied Europe. In October 1940 one of these aircraft photographed the port of Stettin (now Sczecin in Poland) in the Baltic. In the following month Marseilles in the south of France, and Trondheim in Norway, also surrendered their secrets to one of these aircraft. Although the reconnaissance units comprised only a small proportion of the Spitfire force, the value of the intelligence they secured was out of all proportion to their numbers.

For fighter pilots there was the excitement and spectacle of combat, and the sight of falling enemy planes. Compared with that, a lone reconnaissance Spitfire sneaking out to photograph a target perhaps weeks before an attack, and again after it, might seem a relatively unimportant matter. Yet assuredly that was not the case. Without a successful pre-strike reconnaissance, an attack on a target of any complexity was unlikely to be effective: those planning an attack could only guess at the location of the target's vulnerable areas and the location of its defences. Similarly, without post-strike reconnaissance the planners could not know with certainty whether an attack had been successful or if it needed repeating. Nor was the reconnaissance task an easy option for the pilots concerned. It took a special kind of courage to venture, alone, on a flight of several hundred miles into enemy territory, risking all to secure the precious pictures.

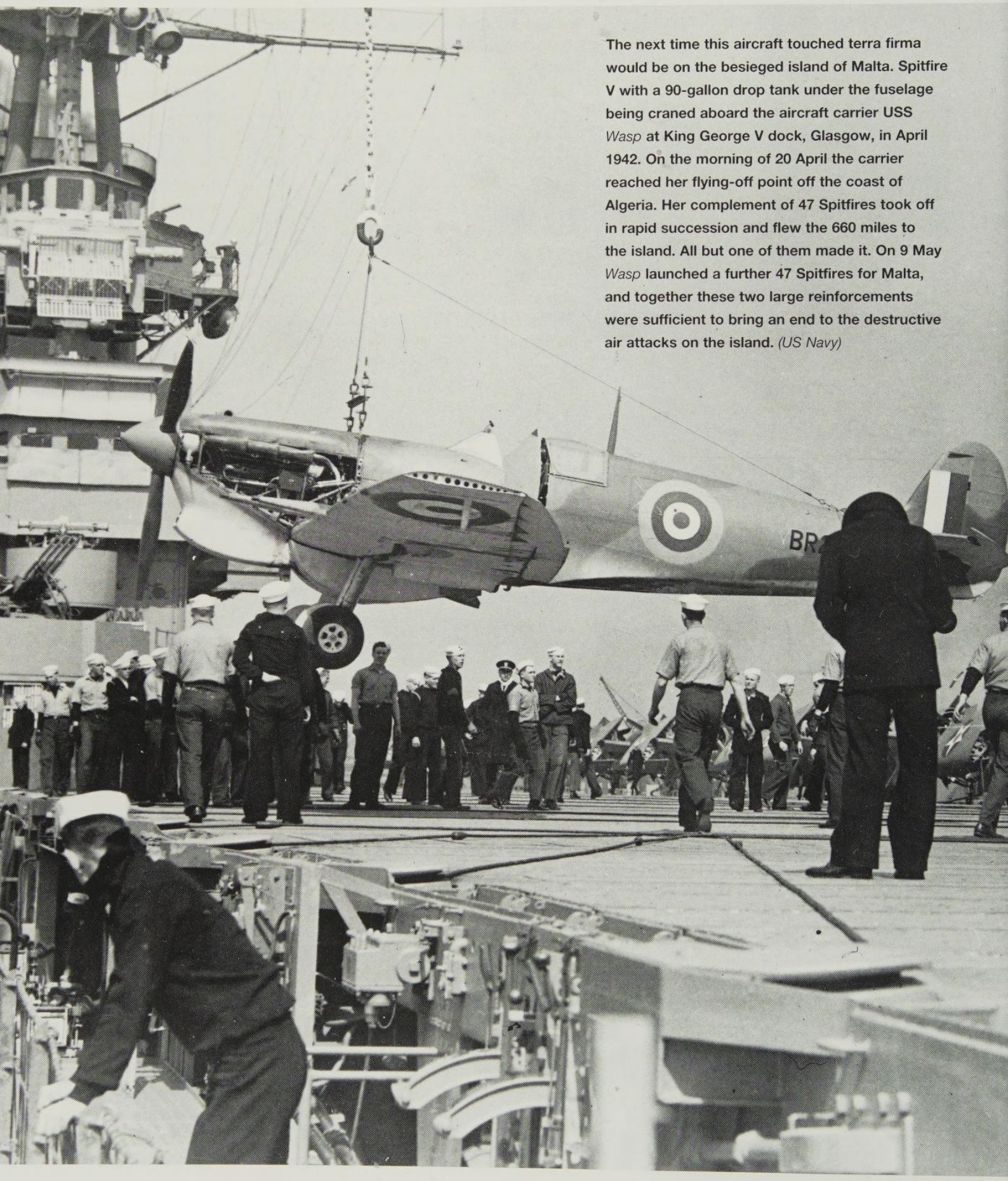
Spitfires to Malta

During the first two and a half years of the war all Spitfire fighter squadrons remained in Great Britain to defend the homeland. But in the spring of 1942 there was an urgent need to deliver some of these aircraft to a distant theatre of war. Malta, the lynchpin of Allied strategy in the Mediterranean, was wilting under a ferocious aerial bombardment from the Axis air forces. The defenders urgently needed Spitfires to protect them, but how could they get there? The distance to Malta from the nearest airfield in friendly territory, at Gibraltar, was far beyond the fighter's maximum ferry range. Moreover, due to the powerful Axis air and naval blockade there was no question of shipping crated aircraft to the besieged island.

In answer to an urgent request from the RAF, Supermarine engineers modified a batch of

OPPOSITE TOP: A so-called 'pink' Spitfire of the Photographic Reconnaissance Unit, with the port for the sideways-looking camera visible to the left of the fuselage roundel. In fact the aircraft was not really pink: it was off-white with the merest tinge of pink. For the exact shade, look at the bottom of the clouds on an overcast day. These aircraft operated only on days when there was almost continuous cloud cover. They would run in to photograph their targets keeping just below the cloud base. If the aircraft came under attack from fighters or AA guns, the pilot would make a steep climbing turn into cloud to escape. *(Gordon Green)*

OPPOSITE BOTTOM: Into the valley of the shadow of death: dramatic low-altitude oblique photograph of the German heavy cruiser *Admiral Hipper* in dry dock at Brest in January 1941, taken by Pilot Officer J. Chandler flying a Spitfire of the Photographic Reconnaissance Unit. Brest was one of the most heavily defended points in France, and the pilot showed great courage. *(Crown Copyright)*



The next time this aircraft touched terra firma would be on the besieged island of Malta. Spitfire V with a 90-gallon drop tank under the fuselage being craned aboard the aircraft carrier USS *Wasp* at King George V dock, Glasgow, in April 1942. On the morning of 20 April the carrier reached her flying-off point off the coast of Algeria. Her complement of 47 Spitfires took off in rapid succession and flew the 660 miles to the island. All but one of them made it. On 9 May *Wasp* launched a further 47 Spitfires for Malta, and together these two large reinforcements were sufficient to bring an end to the destructive air attacks on the island. *(US Navy)*

Spitfires to carry a 90-gallon drop-tank under their fuselages. These aircraft were carried to Gibraltar by freighter, and assembled on the quayside. As each fighter was completed, it was lifted by crane onto the deck of the aircraft carrier HMS *Eagle*. In March 1942 the aircraft carrier took the first batch of 15 Spitfires to a point off the coast of Algeria. There the fighters took off and flew the rest of the way to Malta. The distance involved, 660 miles, was about as far as from London to Prague. And, should it prove necessary to fight their way into their new bases, the Spitfires had to retain a reserve of fuel for that purpose.

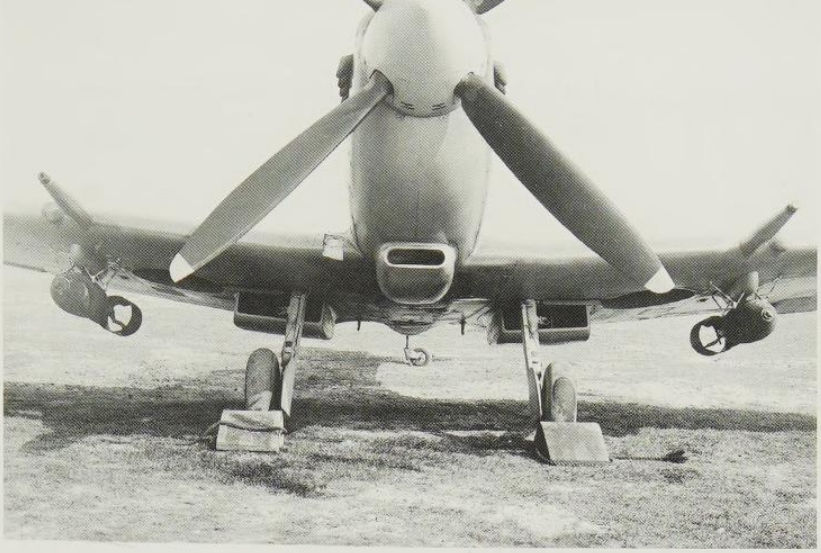
The two largest Spitfire delivery operations took place in April and May 1942, in each of which the big carrier USS *Wasp* launched 47 fighters. In the course of 13 separate reinforcement operations between March and October 1942 a total of 385 Spitfires took off from the decks of aircraft carriers for Malta; 367 reached the island safely. During the hard-fought air battles that followed, the Spitfires blunted the Axis air attacks and played an important part in lifting the siege of the island.

The Spitfire finds further new roles

Until the autumn of 1942 the Royal Navy lacked a high performance carrier fighter that could engage the latest enemy fighters on anything like equal terms. To meet that need, Supermarine modified the Spitfire to have an arrester hook for deck landings. This new version was named the Seafire, and its development went forward in parallel with that of the Spitfire. In September 1943, operating from five small aircraft carriers, just over a hundred Seafires provided vital air cover for the invasion of Italy until landing grounds for fighters could be established ashore.

Also during the mid-war period Spitfires began carrying bomb racks for two 250lb bombs under the wings, or a single 500-pounder under the fuselage. For the remainder of the conflict, as the Allies imposed air supremacy over each combat zone in turn, Spitfires flew an increasing proportion of their missions in the fighter-bomber role.

One interesting development at this time resulted in a small number of Spitfires being



ABOVE: Spitfire IX modified for the fighter-bomber role, carrying two 250lb bombs. *(Crown Copyright)*

BELOW: Five Spitfires were modified as floatplanes, intended for use in military operations that failed to materialise. The floats were designed by Arthur Shirvall, who had designed the floats for the pre-war Schneider Trophy racing seaplanes. *(Alfred Price Collection)*

ABOVE: Spitfire XIs of the USAAF 14th Photo Squadron, 7th Photo Group, based at Mount Farm near Oxford in 1944. The unit engaged in taking pre-strike and post-strike photos of targets attacked by US heavy bombers. *(Weitner)*

modified into floatplanes. These were intended to operate from a base established beside an uninhabited island in the Dodecanese, with a submarine in support. The object was to engage Axis transport planes flying vital supplies to the garrisons of other islands in the area. The idea came to nothing, but it had produced a further unusual role in which the Spitfire could perform.

The Mark XII and the Mark XIV Spitfires were air superiority fighters powered by the larger and more powerful Griffon engine. The same unit powered the Mark XIX, the definitive long-range reconnaissance variant of the Spitfire. This variant brought a huge advance in performance over its predecessors, being capable of cruising to its target at altitudes above 45,000ft. That increased operating altitude gave the Mark XIX a useful margin of safety, even when enemy jet fighters attempted to intercept it.

The final Spitfire derivative produced, a Seafire Mark 47, emerged from the assembly hangar at South Marston in January 1949. That marked the end of a production process that had lasted 11 years and turned out just over 22,000 aircraft.

RIGHT: Spitfire XII, the first variant fitted with the Griffon engine. This version was optimised for low-altitude operations and was built only in small numbers. *(RAF Museum/Charles Brown)*

TOP LEFT: A Seafire 47 comes in to land on HMS *Illustrious* in 1947. After taking the arrester wire, the aircraft is plucked from the sky... *(RAF Museum/Charles Brown)*

TOP RIGHT: ...and slammed down on the deck. Note the main wheel undercarriage oleo legs at full compression. *(RAF Museum/Charles Brown)*

MIDDLE: As the Seafire is brought firmly to a halt, the deck handling crew moves swiftly to free the hook from the wire. Once this is done the aircraft will taxi forwards to the other side of the lowered crash barrier, to allow the next aircraft to land. Although these three photos give the impression of being the same aircraft, in fact they depict three different Seafires. *(RAF Museum/Charles Brown)*

BOTTOM: Not all deck landings went that well! This Seafire III belonging to No 807 Squadron was landing on HMS *Hunter* in light wind conditions in the Indian Ocean. The aircraft came in fast, bounced over all of the arrester wires, then leapt over the crash barrier tearing off both main-wheel legs and the tail wheel. It came to a halt and stood on its nose, as seen here, for a few seconds before the law of gravity took command of the situation. Then the tail fell heavily to the deck, causing further damage. The aircraft was pronounced 'damaged beyond repair' and, after reusable items had been removed, it was 'tested for buoyancy' (Navy-speak for being pushed over the side). *(Alfred Price Collection)*

'THE LAST!'
P5 889

After the war Spitfires were widely exported, and equipped front-line fighter and reconnaissance units in 27 nations. The Spitfire's combat career did not end in 1945. Both sides flew Spitfires during the first Arab-Israeli war in 1948, and in 1950 the Royal Navy deployed the aircraft carrier HMS *Theseus* with a squadron of Seafires to fight in Korea.

A closely guarded secret for many years was the clandestine sorties flown by reconnaissance Spitfires during the Cold War. RAF Spitfire XIXs photographed ports and other installations in the Peoples' Republic of China during 1951 and 1952. And almost certainly RAF reconnaissance units based in Germany carried out similar flights over Eastern Europe.

The RAF was not alone in sending Spitfires to fly such missions. In October 1948 the Royal Swedish Air Force took delivery of 50 Spitfire XIXs. Many people wondered what that service wanted from so many unarmed reconnaissance planes. Now we know. Recently it was revealed that these aircraft were used to photograph ports and other facilities in the Soviet Union, Poland and East Germany. These aircraft had the national markings painted out and the pilots flew in civilian clothes. The camera magazines were modified so that if there was a danger of capture, the pilot could ruin the film to hide incriminating evidence of spying.

The last operational sortie by an RAF Spitfire took place on 1 April 1954 when a Spitfire XIX of No 81 Squadron based at Seletar, Singapore, photographed an area of Malayan jungle thought to contain Communist guerrillas.

Probably the last-ever offensive missions by Spitfires and Seafires were those flown by the Burmese (now the Union of Myanmar) Air Force during 1955 and 1956, operating against bands of insurgents.

The last flight by a Spitfire in regular RAF Service was by a Mark XIX in June 1957, when an aircraft of the THUM (Temperature and Humidity Measuring) Flight flew a meteorological observation sortie from Woodvale in Lancashire.

The Spitfire was more than a superb fighting machine, important though that was. Many people credit it with saving the British nation from defeat during the grim days of 1940. Such is its unique place in the national psyche that even today its shapely lines and muttered engine note evoke feelings of deep nostalgia among people who lived through those testing times. There will never be another aircraft like the Spitfire. Let us hope there will never need to be.

The pattern of development

From the time of its first flight, the Spitfire underwent a never-ending series of incremental improvements, to keep it at the forefront of fighter design. Rolls-Royce provided the impetus for this pattern of developments by squeezing progressively greater power levels from the Merlin, and later the Griffon, series of engines. The evolution of these engines is covered in greater detail in the sections later in this chapter. A parallel line of development attended the Seafire, the naval version of the aircraft.

In aircraft design one never gets something for nothing, and there was a downside to this development process. Each increase in engine power brought with it an increase in engine weight. Also, in producing the extra power the engine guzzled fuel at a faster rate. So, to restore the range of the aircraft it required larger capacity (and therefore heavier) fuel tanks.

To convert the additional engine power into thrust, the propeller acquired additional blades. During its development life the Spitfire progressed from a two-blade propeller to a three-blade, to a four-blade, and then to a five-blade propeller. The greater the number of blades, the greater the weight of the propeller and the greater the twisting force exerted when the engine ran at full power. Throughout the Spitfire's career there were incremental increases in the area of the tail surfaces, to restore their effectiveness. Then, for the Spitfires Mark 22 and 24 and the Seafires Mark 46 and 47, there were redesigned tail surfaces with a greatly increased area. The Seafires Mark 46 and 47 were fitted with two three-blade contra-rotating propellers, which effectively cancelled out the twisting forces and made these variants much easier to handle.

OPPOSITE TOP: Spitfire XIX reconnaissance aircraft about to take off for delivery to the Royal Swedish Air Force in 1948. Only recently has it been revealed that during the early part of the Cold War these aircraft flew clandestine photographic reconnaissance missions over the Soviet Union and its satellites in Eastern Europe. *(Vickers)*

OPPOSITE BOTTOM: PS888, a Mark XIX of No 81 Squadron based at Seletar, Singapore. On 1 April 1954 it took off on the last operational flight by a Spitfire in RAF service, to photograph an area of jungle in Johore thought to contain communist guerrillas. To mark this special occasion ground crewmen had painted 'The Last' on the aircraft's nose. *(George Yallop)*

The hard-won lessons of combat led to other weight increases. The RAF demanded armour protection for the pilot and vulnerable parts of the structure. Also, as the war progressed the Spitfire carried a more powerful (and therefore heavier) armament.

While the fighter flew straight and level, those progressive increases in weight did not matter much. But when the pilot threw his Spitfire around the sky in combat it was a different matter. If he pulled 6G in a tight turn, every part of the aircraft weighed six times as much. If the structure was not strong enough to withstand the additional forces, it would simply collapse. So, to cope with each major increase in weight the airframe had to be redesigned to increase its strength and maintain the safe

TOP LEFT: Early Mark I Spitfire, with a fixed-pitch two-bladed propeller. *(Crown Copyright)*

MIDDLE: Three-bladed constant-speed propeller, fitted to late Mark Is and Marks II, IV, V, and XIII. *(Crown Copyright)*

MIDDLE: Four-bladed constant-speed propeller, fitted to Marks VI, VII, VIII, IX, X, XI, XII and XVI. *(Crown Copyright)*

BOTTOM: Five-bladed constant-speed propeller, fitted to Spitfire Marks XIV, XVIII, XIX, 21, 22 and 24 and the Seafire 45. *(Crown Copyright)*

BELOW: Two three-bladed contra-rotating constant-speed propellers, fitted to production Seafire Marks 46 and 47, and a few Spitfire 21s. *(Crown Copyright)*

load factors. And, naturally, each such bout of strengthening brought a further twist in the spiral of increasing weight.

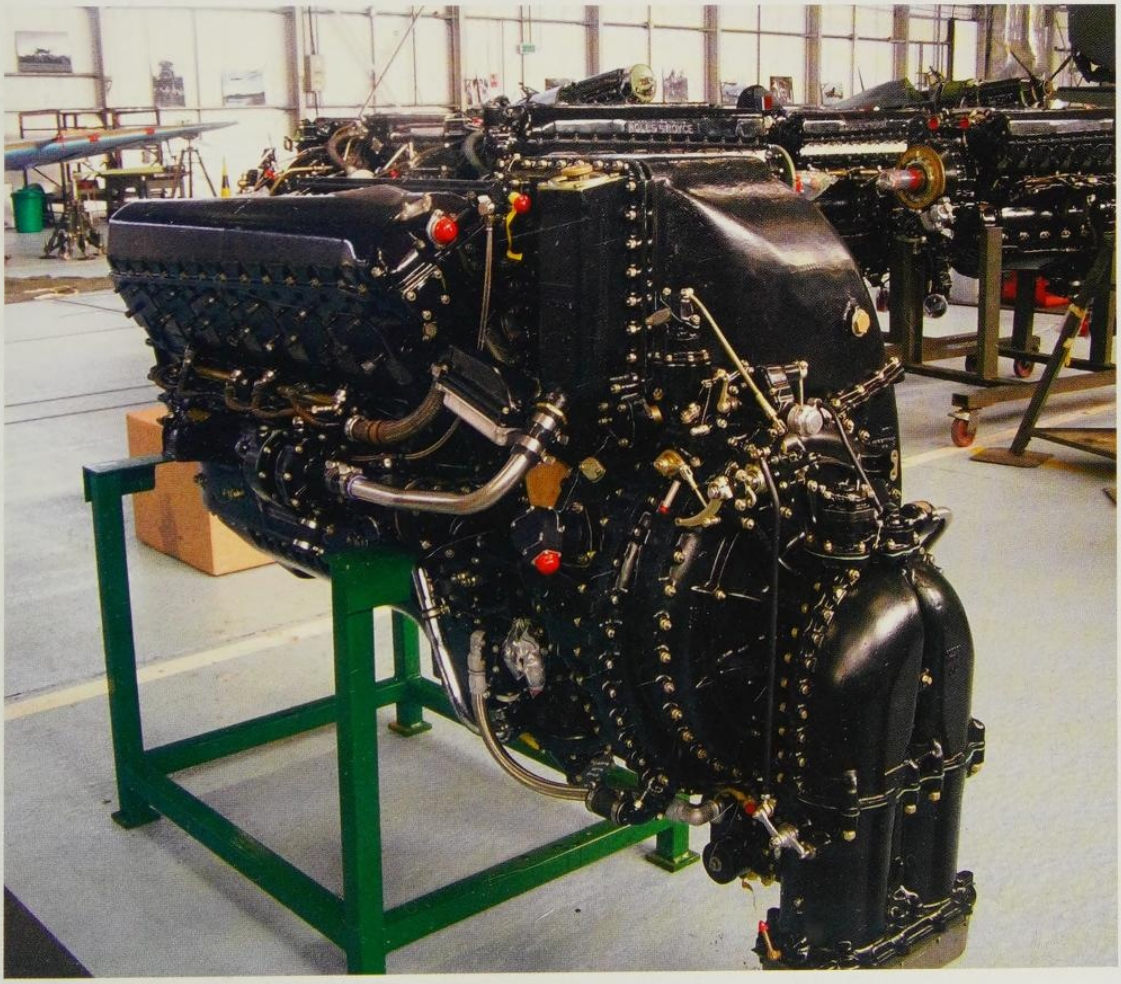
Cumulatively, the various changes had a huge effect on the Spitfire's fighting ability. Compared with the 1,050hp of the Spitfire I, the Seafire 47's engine developed 2,350hp. Against the Mark I's top speed of 362mph, the Seafire 47 could achieve 452mph. The Mark I's maximum rate of climb was 2,195ft per minute, while that of the Seafire 47 was 4,800ft per minute. A three-second burst from the Mark I's eight machine guns spewed out rounds weighing 8lb. A similar burst from the Seafire 47's four 20mm cannon loosed off rounds weighing 40lb. Also, more ominously, there was a huge increase in maximum take-off weight, from 5,280lb for the Mark I to 12,500lb for the Seafire 47. To put that increase in maximum weight another way, the Seafire 47 weighed as much as a Spitfire I plus 34 passengers each weighing 12 stone and carrying the standard airline baggage allowance of 44lb.

The Rolls-Royce Merlin

In the early 1930s the board of directors of Rolls-Royce saw that a new and more powerful engine for fighters would be required before the end of the decade. At that time the 21-litre RR Kestrel Vee-12 engine was in general service in the RAF to power biplane fighters such as the Nimrod, Fury and Demon. But the Kestrel was approaching the end of its development potential at around 700hp.

Accordingly Rolls-Royce decided, as a private venture, to design and build a new 27-litre Vee-12 engine with a target output of 1,000hp. Initially designated the PV 12, the aircraft that later became the Spitfire and the Hurricane were designed to accommodate it. In 1934 the new engine, by then named the Merlin, completed its first 100 hours running test at 790hp. In 1936 the Merlin completed a type test at 975hp.

During the war a bewildering array of different marks of the Merlin were manufactured. So far as the story concerns the Spitfire, these



LEFT: The Packard-built Merlin 266 engine, recently overhauled by Retro Track and Air, with two-stage supercharging, powered the Spitfire XVI. *(P. Blackah/ Crown Copyright)*

RIGHT: Spitfire Mark IX MK356 of the Battle of Britain Memorial Flight in the markings of No 433 Squadron RCAF, with which it flew during the Normandy invasion in 1944. *(Crown Copyright)*

fell into three groups. First came the Merlin III, fitted to the Spitfire I, which developed 890hp for take-off and 1,000hp at 15,000ft altitude. Secondly, there was the Merlin 45 series of engines, fitted to the Spitfire V and VI, which developed around 1,230hp for take-off and 1,200hp at 17,500ft altitude. And thirdly, there was the Merlin 61 series of engines with two-stage superchargers, fitted to the Spitfire IX, XI, and XVI, which developed 1,450hp at sea level, 1,550hp at 11,000ft and 1,370hp at 24,000ft.

The Merlin III was fitted with a single-stage, single-speed supercharger. In the early days of the war only 85 octane fuel was available, so the maximum boost pressure obtainable was limited to plus 6lb to avoid detonation in the cylinders.

The Merlin 45 was developed from the Merlin III, with a redesigned air intake system and a more efficient supercharger. These and other changes increased the power from 900hp to 1,100hp. At the same time there was an increase in the available fuel octane value, from 85 to 100. That increased the maximum boost pressure to plus 12lb, giving 1,230hp for take-off.

The engine's final phase of improvement was with the Merlin 61 series. These had a two-stage supercharger with an intercooler between the supercharger and the cylinders. This engine had originally been designed to power a high-altitude version of the Wellington bomber, but Ernest Hives, Chief Experimental Engineer at Rolls-Royce, asked 'What would happen if we put that engine into a Spitfire?' At first it seemed the difficulties were insurmountable. The new engine was 9in longer than the Merlin 45, and there was the added complexity of the additional cooling system and a radiator for the intercooler. However, engineers at Derby completed the design and installation of the new engine in a matter of weeks.

In September 1941 an experimental Spitfire was flight-tested with the new version of the Merlin, and the improvement in performance was startling. The two-stage supercharger maintained plus 9lb of boost pressure up to 30,000ft, and at that altitude it developed 1,000hp compared with the 500hp available from the Merlin 45. The new engine increased the fighting altitude of the Spitfire by 10,000ft,

OPPOSITE: At the time of writing Seafire 47 VP441 is the youngest survivor from the Spitfire/ Seafire line, having made its first flight in November 1947. It is also the sole airworthy example of this variant, having made its first post-restoration flight in April 2004. *(Bobby LeBlanc)*

from around 30,000ft to around 40,000ft, and it added more than 40mph to the fighter's maximum speed.

The new engine modified for installation in the Spitfire was designated the Merlin 61, and it powered the Spitfire IX which entered service in July 1942. The new Spitfire variant was rushed into service to combat the Focke Wulf 190, which had been giving the Spitfire V squadrons a difficult time. Pitted in mock combat against a captured Fw 190, the Spitfire IX was found to match the German fighter's performance almost exactly.

It's important to note that many of the Spitfires flying today are not fitted with the original-equipment variants of the Merlin engine, due to availability. Many restored aircraft use later Merlin engines that may not be totally authentic for the specific mark of Spitfire concerned, for example the Battle of Britain Memorial Flight's Mark VB AB910 is fitted with a Merlin 35, whereas it would have originally been fitted with a Merlin 45.

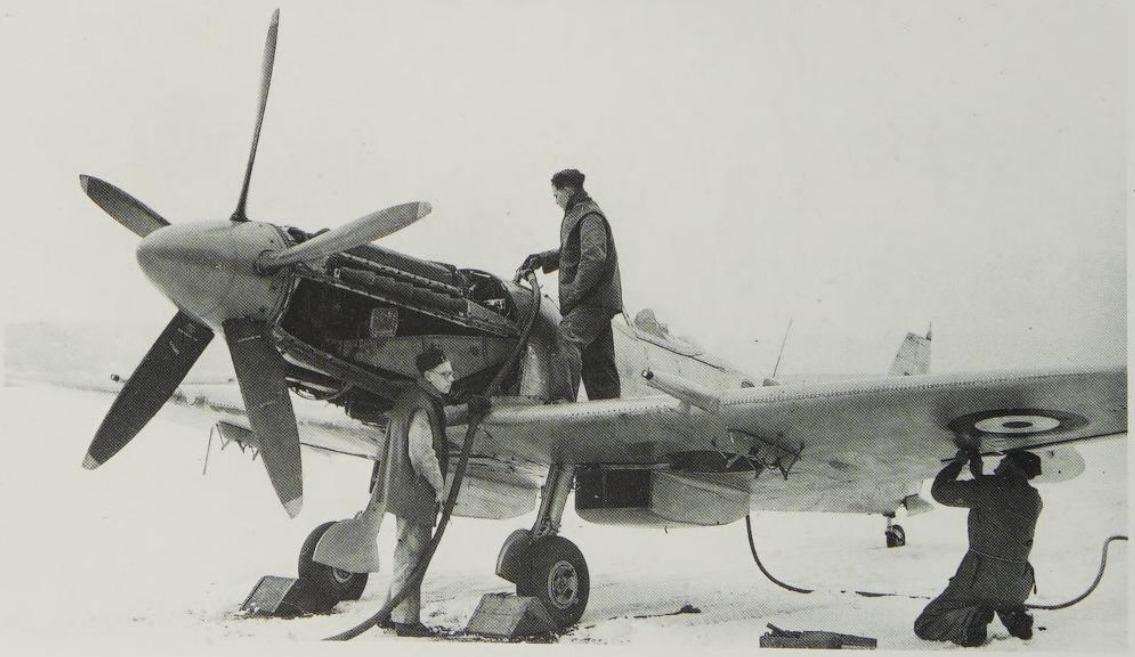
The Rolls-Royce Griffon

Following the start of hostilities in 1939, the government instructed Rolls-Royce to begin work on a new Vee-12 liquid-cooled engine that would be similar in layout to the Merlin, but which would deliver significantly greater power. An essential requirement of the new engine was that it should be capable of installation in any existing Merlin-powered aircraft. The resultant engine, named the Griffon, had a volume of 36.7 litres – just over one quarter greater than the Merlin. Moreover, by some inspired juggling of the peripherals its designers contrived to keep the Griffon's frontal area within 6 per cent, and the overall length to within 3in, of those of the earlier engine.

The first version of the new engine to enter service in the RAF was the Griffon III, fitted to the Spitfire XII. This developed a maximum of 1,730hp at 750ft and 1,490hp at 14,000ft. The Spitfire was optimised for the low-altitude air superiority role, and the early Griffon was fitted with a single-stage supercharger. The Seafires Mark XV and XVII also employed this engine.

The next step in Griffon development, so far as the Spitfire was concerned, was the Mark 61, which featured a two-stage supercharger similar to that fitted to the Merlin 61. This engine entered service early in 1944 aboard the Spitfire XIV, and developed 1,540hp for take-off, 2,035hp at 7,000ft and 1,820hp at 21,000ft. This engine and others in the series powered the Spitfire Marks XVIII, XIX, 21, 22 and 24, and also the Seafire 45.

The final aircraft in the Spitfire/Seafire series, the Seafire 46 and 47, were powered by a Griffon 87 engine that was similar to the Mark 61 but had a modified gearbox to allow it to drive two three-bladed contra-rotating airscrews.



RIGHT: Refuelling a Spitfire XIV. Note the revised engine mounting to accommodate the larger and heavier Griffon engine. *(Costain)*

ROYAL NAVY
139

Squaring up to the enemy

During the first two years of the war the Spitfire Marks I, II and V were neck and neck in terms of air combat performance, compared with their Luftwaffe equivalents the Messerschmitt 109E and the Messerschmitt 109F. Then in the autumn of 1941 the Luftwaffe introduced the Focke Wulf Fw 190, which possessed a clear performance advantage over the Spitfire V.
In June 1942 the RAF captured an intact Fw 190, which it tested in mock combat with a range of Allied fighters. The tests confirmed what RAF Fighter Command pilots had been complaining about: the Fw 190 had a speed advantage over the Spitfire V of 25 to 30mph at all altitudes from 2,000ft to 21,000ft. The German fighter could out-climb, out-dive and out-accelerate the Spitfire V at all altitudes and moreover it had a superior rate of roll. Indeed, the only aspect in which the Spitfire V held the advantage was that it turned tighter than the Fw 190.

In July 1942 the Mark IX Spitfire entered service, powered by the Merlin 61 engine with a two-stage supercharger and developing 1,550hp at 11,000ft. When a Mark IX was tested in mock combat against the captured Fw 190, the two fighters were found to be almost equal in most aspects of combat performance. Against the Messerschmitt 109G, the Spitfire IX was generally superior.

Early in 1944 the Spitfire XIV entered service, powered by the Rolls-Royce Griffon 61 engine fitted with a two-stage supercharger and developing 2,035hp at 7,000ft. In mock combat with the Fw 190A and the Messerschmitt 109G, the Spitfire XIV demonstrated a clear margin of superiority. The excerpts opposite were taken from the combat trials report issued by the Air Fighting Development Unit at Duxford.

BELOW: Jeffrey Quill nudging his Spitfire XIV in close to the photographic aircraft. Quill judged the Griffon-powered Mark XIV to be the most effective fighter variant of them all. *(RAF Museum/Charles Brown)*

Combat trial of Spitfire XIV against the Fw 190

Maximum Speed. From 0–5,000ft and 15,000–20,000ft the Spitfire XIV is only 20mph faster; at all other heights it is up to 60mph faster than the Fw 190A.

Maximum Climb. The Spitfire XIV has a considerably greater rate of climb than the Fw 190A.

Dive. After the initial part of the dive, during which the Fw 190 gains slightly, the Spitfire XIV has a slight advantage.

Turning Circle. The Spitfire XIV can easily turn inside the Fw 190, though in the case of a right-hand turn this difference is not quite so pronounced.

Rate of Roll. The Fw 190 is very much better.

Conclusions. In defence, the Spitfire XIV should use its remarkable maximum climb and turning circle against any enemy aircraft. In the attack it can afford to "mix it" but should beware the quick roll and dive. If this manoeuvre is used by an Fw 190 and the Spitfire XIV follows, it will probably not be able to close the range until the Fw 190 has pulled out of its dive.

Combat Trial of Spitfire XIV against the Messerschmitt 109G

Maximum Speed. The Spitfire XIV is 40mph faster at all heights except near 16,000ft, where it is only 10mph faster.

Maximum Climb. The same result: at 16,000ft the two aircraft are identical, otherwise the Spitfire XIV out-climbs the Me 109G. The zoom climb is practically identical when the climb is made without opening the throttle. Climbing at full throttle, the Spitfire XIV draws away from the Me 109G quite easily.

Dive. During the initial part of the dive the Me 109G pulls away slightly, but when a speed of 380mph is reached, the Spitfire XIV begins to gain on the Me 109G.

Turning Circle. The Spitfire XIV easily out-turns the Me 109G in either direction.

Rate of Roll. The Spitfire XIV rolls much more quickly.

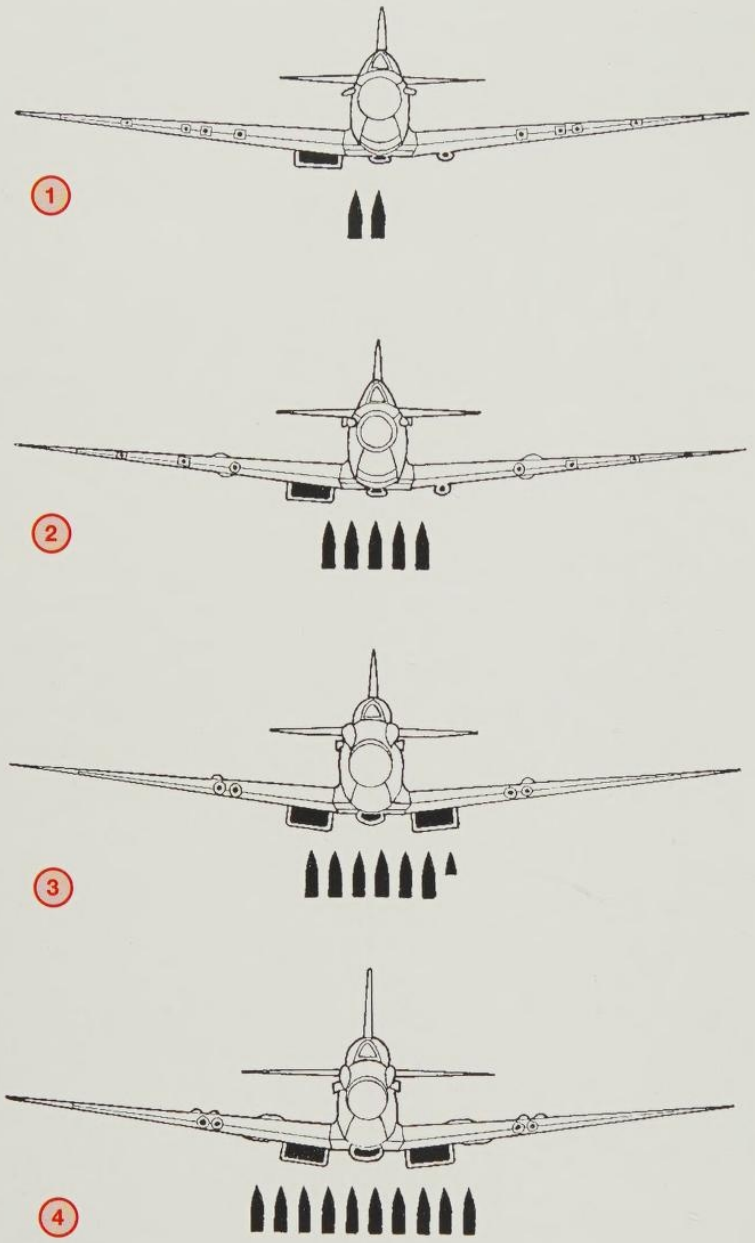
Conclusion. The Spitfire XIV is superior to the Me 109G in every respect.

Authors' note: The correct abbreviation for the Messerschmitt 109 was 'Bf 109'. However, the latter abbreviation is not to be found in RAF documents originated in World War Two. Throughout this 1944 official report the abbreviation 'Me 109' was used, and in the interests of authenticity it has been retained.

One factor that should be borne in mind reading this report is that in 1944 the RAF did not possess examples of the latest versions of the Focke Wulf 190 or the Messerschmitt 109, or even the jet-propelled Messerschmitt 262. Nevertheless, the trials report illustrates well the dramatic effect of the various modifications to improve the 'fightability' of the Spitfire throughout the war.

ABOVE: The Spitfire XIV was superior to the Focke Wulf Fw190A in all aspects of combat performance except for rate of roll. *(Romm)*

BELOW: The Spitfire XIV was greatly superior to the Messerschmitt Bf 109G in almost every aspect of combat performance. *(Schliephake)*



ABOVE: Line drawing showing the increases in firepower during the development of the Spitfire. Each 'shell' represents 4lb of rounds fired. *(Crown Copyright)*

RIGHT: Armourer loading a belt of 20mm rounds into the starboard Hispano cannon of a Spitfire IX. *(Crown Copyright)*

Spitfire armament

The original armament fitted to Mark I and II Spitfires comprised eight .303in Browning machine guns, each with 300 rounds of ammunition. Weight of rounds fired in a three-second burst was 8lb **(1)**.

In the late spring of 1940 a few Spitfire IBs entered service, with the Browning machine guns removed and two 20mm Hispano cannon, each with 60 rounds, fitted in their place. In action these cannon performed unreliably, and after a short time the Spitfire IB was withdrawn from service. By the end of 1940 the problems of the Hispano cannon had been resolved and the Spitfire IB re-entered service, with two Hispano cannon but retaining the four Browning machine guns in the outer positions. That armament combination was fitted to Spitfire IIBs and the large number of VBs produced in 1941. Weight of rounds fired in a three-second burst was 20lb **(2)**.

During 1942 the C-type wing was introduced on the Spitfire V production line, with provision to carry four 20mm Hispano cannon each with 120 rounds, or eight .303 Browning machine guns each with 350 rounds, or two 20mm cannon and four machine guns. The last-named weapon combination was by far the most used.

Early in 1944 a new armament combination appeared, with the introduction of the E-type wing on the production line. This carried two 20mm Hispano cannon each with 120 rounds, and two .5in Browning machine guns each with 250 rounds. The E-type wing was fitted to late production Spitfires Mark IX and XIV, and all Mark XVIs and XVIIIs. Weight of rounds fired in a three-second burst was 26lb **(3)**.

The final gun armament comprised four 20mm Hispano cannon with 175 rounds for each inboard weapon, and 150 rounds for each outboard weapon. This armament was fitted to all Spitfires Mark 21, 22 and 24, and all Seafires Mark 45, 46 and 47. Weight of rounds fired in a three-second burst was 40lb **(4)**.

Operating in the fighter-bomber role the Spitfire V, and subsequent marks listed in this section, could carry two 250lb bombs or one 500-pounder. The exception was the Seafire 47, which could carry two 500lb bombs. Alternatively, the Spitfire XVIII and the Seafires Mark XVII and 47 could carry four 60lb rocket projectiles.

The main production variants of the Spitfire family

Spitfire: the main production variants

Mark I – First production fighter version, powered by the Rolls-Royce Merlin III engine. Made its maiden flight in May 1938 and entered service the following September.

Mark I Reconnaissance Aircraft – Designated from 1A to 1G depending on the configuration of the cameras and the amount of additional fuel tankage. The first such aircraft entered service in November 1939.

Mark II – Fighter version similar to the Mark I, but fitted with the Merlin XII engine. Entered service in September 1940.

Mark V – Fighter version similar to the Mark I, but fitted with the Merlin 45 series engine. The Mark V entered service in February 1941 and was built in very large numbers. Later in the war it became the first variant to be fitted with bomb racks to allow it to operate in a fighter-bomber role.

Mark VI – High-altitude interceptor fighter similar to the Mark V, but fitted with a pressurised cabin and longer-span wing. Power was from a Merlin 47 engine. The Mark VI was built in small numbers and entered service in April 1942.

Mark VII – High-altitude interceptor fighter, similar to the Mark VI but powered by the Merlin 61-series engine with two-stage supercharger. Built in moderate numbers, the first squadron became operational in April 1943.

Mark VIII – General-purpose fighter similar to the Mark VII but without the pressurised cabin.

BELOW: Jeffrey Quill airborne in Spitfire I P9450, the 600th production aircraft, in April 1940. This Spitfire served with No 64 Squadron during the Battle of Britain. *(Vickers)*

Entered service in the summer of 1943. Built in large numbers, all of which served with units based outside the United Kingdom. This variant also operated in the fighter-bomber role.

Mark IX – General-purpose fighter version based on the Mark V, but fitted with the Merlin 61-series engine. Entered service in June 1942. This variant was intended as a stopgap, pending large-scale production of the Mark VIII, but in the event the Mark IX remained in production until the end of the war. Late production aircraft were fitted with cut-back rear fuselages and teardrop canopies. This variant also operated in the fighter-bomber and fighter-reconnaissance roles.

Mark X – Photographic reconnaissance variant with enlarged internal fuel tankage, fitted with the Merlin 61-series engine and a pressurised cabin. Entered service in May 1944. Built in small numbers.

Mark XI – Photographic reconnaissance variant similar to the Mark X but without the pressurised cabin. Despite the later mark number, the Mark XI entered service in December 1942, long before the Mark X. The Mark XI became the most-used photographic reconnaissance variant during the mid-war period.

Mark XII – Fighter version based on the Mark V but fitted with the Griffon III engine with a single-stage supercharger. Built in moderate numbers as a low-altitude fighter, with clipped wings. Entered service in February 1943.

Mark XIV – Fighter version similar to the Mark VIII but fitted with the Griffon 61-series engine with two-stage supercharger. This variant entered service in February 1944. A fighter-reconnaissance version of the Mark XIV also appeared. The variant was built in large numbers and final production aircraft featured a cut-back rear fuselage and teardrop canopy.

Mark XVI – General-purpose fighter version similar to the Mark IX, but powered by the Merlin 266 engine produced under licence in the USA by the Packard Company. Mark IXs

LEFT: Taken in May 1944 shortly before the D-Day invasion of France, this photograph depicts 43 Spitfire IXs. That represented about one week's production of these aircraft at the huge assembly plant at Castle Bromwich near Birmingham. *(Vickers)*

ABOVE: Interior of the giant assembly hall at Castle Bromwich, pictured in the spring of 1945. Low-backed Spitfire XVIs are seen in the final stages of construction. *(Vickers)*

and Mark XVIs were produced side-by-side at the Castle Bromwich plant and their external appearance was almost identical. The Mark XVI entered service in September 1944. Late production aircraft were fitted with a cut-back rear fuselage and a teardrop canopy. This variant also operated in the fighter-bomber role.

Mark XVIII – Fighter-bomber version similar in external appearance to the late-model Mark XIV, powered by a Griffon 61-series engine, and fitted with a teardrop canopy. This variant featured a redesigned and strengthened wing and carried additional fuel tanks in the rear fuselage. A fighter-reconnaissance version of the Mark XVIII also appeared. Built in moderate numbers, it entered service in 1945 just too late to see action.

RIGHT: Mark 22 showing the revised wing shape, with a strengthened internal structure, employed in Spitfire Marks 21, 22 and 24 and Seafire Marks 45, 46 and 47. *(Vickers)*

Mark XIX – This photographic reconnaissance variant combined the Griffon 61-series engine and a pressurised cabin that was a marked improvement over that fitted to the Mark X. It entered service in the summer of 1944 and became the most-used reconnaissance variant during the final year of the war. The Mark XIX remained in front-line service in the RAF until 1954.

Mark 21 – The unwieldy Roman numbers for variants now gave way to Arabic numbers. The Mark 21 was a fighter version with a redesigned and strengthened wing and fuselage, fitted with the Griffon 61-series engine. It entered service in April 1945 and saw some action before the war ended. Built in moderate numbers.

Mark 22 – Fighter version similar to the Mark 21, but with a cut-back rear fuselage and

bubble canopy. Powered by a Griffon 61-series engine and fitted with an enlarged tailplane, fin and rudder. Entered service in November 1947 and became the main post-war production variant. It remained in service with Royal Auxiliary Air Force squadrons until 1951.

Mark 24 – Fighter version based on the Mark 22, powered by a Griffon 61-series engine. Fitted with two additional fuel tanks in the rear fuselage and wing fittings to carry six 60lb rockets. Only one unit, No 80 Squadron, operated this variant. The type remained in front-line service in the RAF until January 1952.

Seafire: the main production variants

Mark IB – Initial navalised version of the Seafire, based on the Spitfire V. Fitted with arrester hook and slinging points, but the wings could not fold.

Mark IIC – Based on the Spitfire V, with a strengthened wing that could not fold. Otherwise naval equipment as fitted to the Mark IB.

Mark III – Similar to the Mark IIC, but with folding wings and powered by a Merlin 55 engine. Produced in large numbers.

Mark XV – Navalised version of the Spitfire XII powered by the Griffon VI engine developing 1,750hp. Fitted with folding wings. The sudden jump in the mark number, from III to XV, was due to the decision to interleave Seafire Mark numbers with those of late mark Spitfire variants. Thus the Mark XIV was a Spitfire, the Mark XV was a Seafire, the Mark XVI was a Spitfire and the Mark XVII was a Seafire.

Mark XVII – Similar to the Mark XV, but with cut-back rear fuselage and teardrop canopy. This variant featured several detailed improvements including a longer stroke undercarriage, and provision to carry under each wing a 22-gallon drop-tank stressed for retention in combat.

Mark 45 – The unwieldy Roman numbers for Seafire variants now gave way to Arabic numbers. Also, there was another jump in the mark numbers assigned to Seafires, which took them well clear of the Spitfire mark numbers. The Mark 45 was an interim navalised version of the Spitfire 21, powered by a Griffon 61-series engine but lacking folding wings. Produced in small numbers.

Mark 46 – Interim navalised version of the Spitfire 22, fitted with a Griffon 87 engine driving two three-bladed contra-rotating propellers, but lacking folding wings. Produced in small numbers.

Mark 47 – The definitive Seafire variant, this was similar to the Mark 46 but was fitted with a Griffon 88 engine driving a contra-rotating propeller, and folding wings. The wings were strengthened to carry a 500lb bomb under each. The first 14 production aircraft had manual wing-folding, whereas the 15th and subsequent aircraft featured hydraulically powered wing-folding. Production aircraft were equipped for the fighter-reconnaissance role, with provision to carry one vertical and one oblique camera in the rear fuselage.

ABOVE: Griffon-powered Seafire XVII SX336, showing the unusual system of double folding employed on Seafire Marks III, XV and XVII. This allowed these aircraft to be stowed in the low hangar decks of some Royal Navy aircraft carriers. *(Peter R. Arnold)*

Top Gun Spitfire, with fitting tributes

The Royal Air Force did not keep official records of the victory claims of individual aircraft, so no record exists for the top-scoring Spitfire. However, a strong contender for that title is Mark IX serial number EN398. This aircraft first flew in February 1943, and was delivered to RAF Kenley, home of the Canadian Wing comprising Nos 402, 403, 411, 416 and 421 Squadrons.

At about the same time Wing Commander 'Johnnie' Johnson arrived at Kenley to take command of the Canadian Wing. Johnson chose EN398 as his personal aircraft and as a wing leader he was permitted to have his initials, JEJ, painted on his Spitfire in place of the squadron code letters.

Johnson first went into action in EN398 on 3 April 1943, when he shot down a Focke Wulf 190. During his six-month operational tour, flying EN398, Johnson shot down 12 enemy aircraft, shared in the destruction of five more, and inflicted damage on a further seven. On one occasion Squadron Leader Robert McNair borrowed EN398, and he shot down a Fw 190.

Adding up the half shares in victories, EN398 can be credited with the destruction of 15 enemy aircraft and causing damage to seven more. It never had to return early from a mission due to technical failure, and in Johnson's skilful hands it never suffered a scratch in combat.

In September 1943 Johnson moved on to take up a staff appointment, and thereafter life for his once-pampered Spitfire went rapidly downhill. Having achieved so much, by today's standards EN398 would have gone into honourable retirement in some air museum. Alas, that was not the case. A couple of weeks later it suffered damage in an accident. After repair, in January 1944 it went to the aircraft park at Redhill where it remained until May 1945. It then went to the Operational Training Unit at Ouston in Northumberland where, no doubt, it suffered much ill treatment from the novice pilots. In March 1946 it went into long-term storage, and its end came in October 1949 when, without ceremony, remorse or even comment, it went to Henry Bath & Son Ltd for scrapping.

BELOW: Fighter Ace Wing Commander 'Johnnie' Johnson pictured beside his personal Spitfire IX EN398 which he flew while commander of the Kenley Wing from March to September 1943. Flown almost exclusively by Johnson, this aircraft was credited with the destruction of 15 enemy aircraft (including fractional victories) and causing damage to seven more. That probably makes it the most successful Spitfire of them all. The aircraft was scrapped in 1949. *(RAF Museum)*

EN398 was dead, but its soul would go marching on. Early in the 1970s Spitfire IX NH238 was restored to flying trim by Hull Aviation Inc of Sugerland, Texas. As a tribute to Johnnie Johnson, owner Ed Jurist had the Spitfire painted with the fighter ace's personal JEJ marking and the serial number EN398. The aircraft carried those markings for more than a decade. Then Doug Arnold bought it and, repainted in different markings, it went into his collection.

Even that was not the end of the story. In 1976, Spitfire IX MA793 was restored to flying condition in South Africa. Purchased by the Museum of Flying at Santa Monica, California, it became the second Mark IX painted as EN398 with the initials JEJ on the fuselage. That Spitfire currently belongs to the Brazilian airline TAM based at Jundiai/San Carlos airfield, where it retains its JEJ markings and colour scheme. Although both 'cloned' Spitfires carried the serial number EN398, their true identities were publicised and there was no attempt to deceive.

LEFT: Although it bears the serial number and side letters of 'Johnnie' Johnson's Spitfire EN398, this aircraft is in fact Mark IX NH238 painted to look like its famous counterpart in 1972. It was then owned by Ed Jurist of the Confederate Air Force based at Sugerland, Texas. The aircraft later returned to Great Britain and was repainted in other markings. It is currently in long-term storage. *(Ed Jurist)*

RIGHT: Another EN398 clone! Mark IX MA793 wearing the serial number and side letters of 'Johnnie' Johnson's Spitfire EN398, applied when it was owned by the Museum of Flying at Santa Monica, California. It currently belongs to the Brazilian airline TAM, and is on display at the TAM Museum at San Carlos. *(Beccari/Rolls-Royce)*

PILOT of THIS A/C is W/C. JOHNSON, D.S.O. D.F.C. & BAR.
16 Enemy A/c to his credit.
28.2.44 34 to his credit

AIRCRAFT

A.M. Form 78.

Contract No. B/9713/39.

Type SPITFIRE F IX. R.A.F. No. EN. 398. Contractor V. A.

Type of Engine MERLIN 63. Engine Nos.

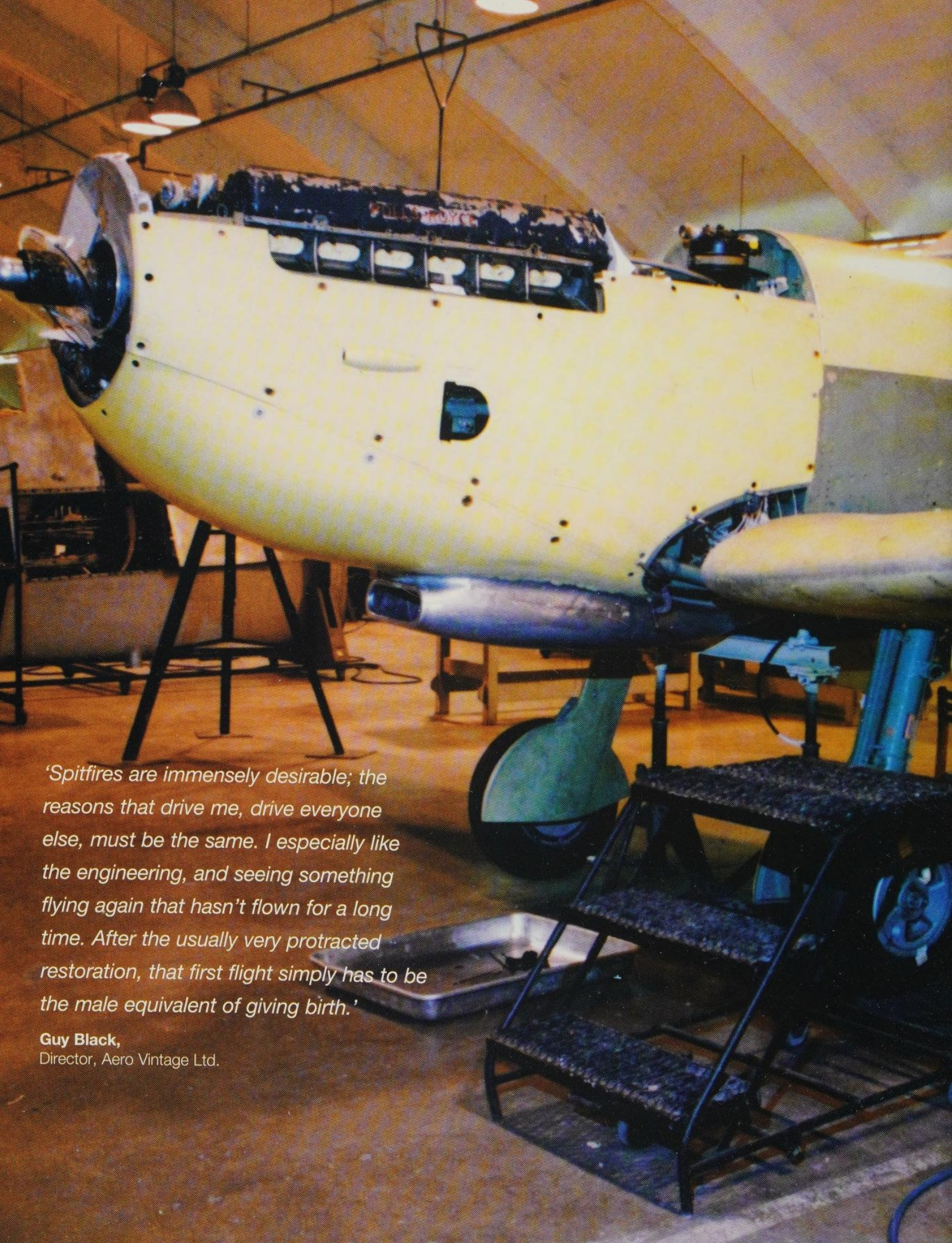
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Taken on Charge of	402 Sqd.	416 Sqd	S.H.Q. KENLEY	MODS A.S.T.	416 Sqd	421 Sqd.	A.S.T. R.I.W.	AW/CN	421 Sqd
Date taken on Charge	18.2.43	23.3.43	4.4.43		16.4.43	27.8.43	26.8.43	27.8.43	31.8.43
Authority	20/2. 84.	141	98		3	89.	ERO	ERO	607

	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Taken on Charge of	~~ASSE~~	CAT. AC. F.B.	A.S.T. R.I.W	AWfCN	83.GRP.SU.	Swell AW. R.I.W.	RW/CN	9 MU	80 OTU
Date taken on Charge	~~BE/SHB~~	24.9.43.	2.1.44	8.3.44	23.3.44	22.8.44	25.11.44	9.1.45	26.5.45
Authority	~~VIII~~	T.154	ERO	ERO	6.	71	ERO	97	

Date	Unit to whom allotted	Authority	Date	Unit to whom allotted	Authority
	402.SQD.	17817.	21.3.46	29 MU ✓	1623/342
			27.10.49	Sold to H. Bath & Son. 10.11.49 41G Se .2	

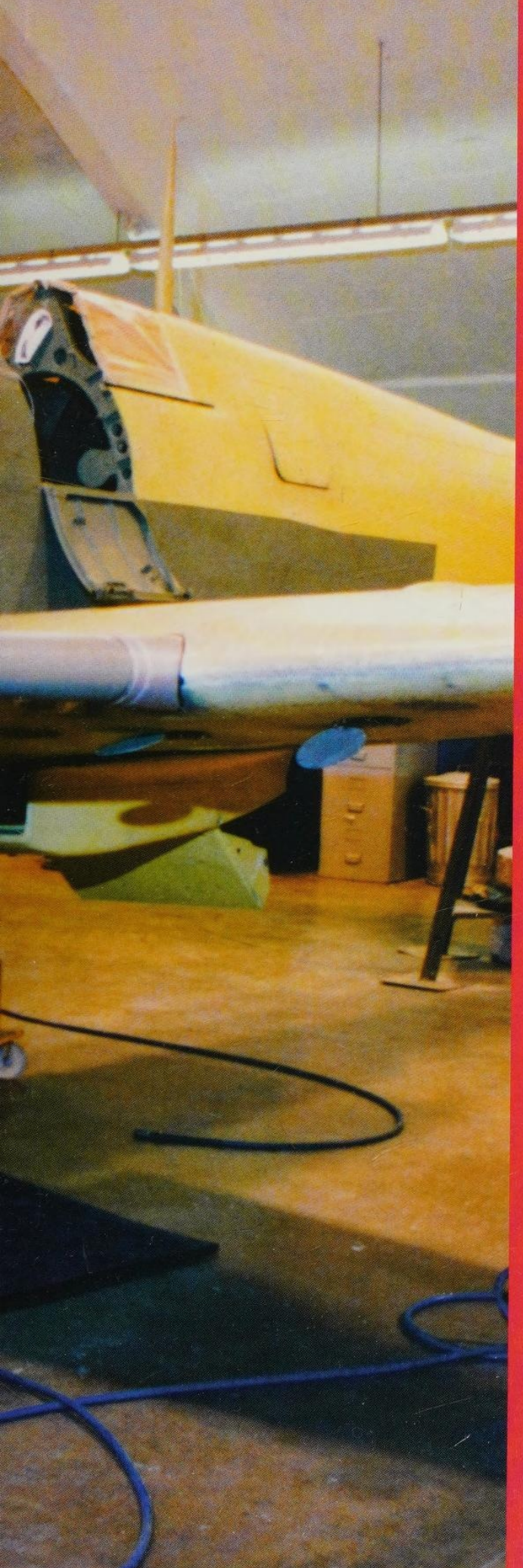
HOME CENSUS MARCH 1946

Provenance: the RAF Form 78 is the official record card for each aircraft. This is the one for probably the most successful Spitfire in action, EN398. At the top of the card someone has written: 'Pilot of this A/C is W/C Johnson DSO, DFC and Bar, 16 enemy A/C to his credit'. From the card we learn that the aircraft was built by Vickers Armstrong and was delivered to No 402 Squadron (based at Kenley) on 18 February 1943. The unit moved away from Kenley in March 1943, but EN398 remained there and transferred to No 416 Squadron. It was recorded as being at the airfield on 4 April 1943. Its next change was to receive modifications at Air Service Training, a civilian contractor. It was still with 416 Squadron on 16 April 1943 and it went to No 421 Squadron (still at Kenley) on 27 July. On 27 August it went to Air Service Training for Repair in Works (to receive a new engine). On 24 September it suffered Category AC damage, which took it to Air Service Training for repairs which lasted until 2 January 1944. On 23 March 1944 it was delivered to No 83 Group Support Unit (at Redhill) to await allocation to a unit. It remained there until 9 January 1945, when it was delivered to No 9 Maintenance unit. Then on 24 May it went to No 80 Operational Training Unit at Ouston. On 21 March 1946 the aircraft made its last flight to No 29 Maintenance Unit at High Ercall, where it was placed in long-term storage. There it remained until 27 October 1949, when it was sold to Henry Bath and Son for scrap. *(Crown Copyright)*



'Spitfires are immensely desirable; the reasons that drive me, drive everyone else, must be the same. I especially like the engineering, and seeing something flying again that hasn't flown for a long time. After the usually very protracted restoration, that first flight simply has to be the male equivalent of giving birth.'

Guy Black,
Director, Aero Vintage Ltd.



(Photo: Paul Harrison)

Chapter Two

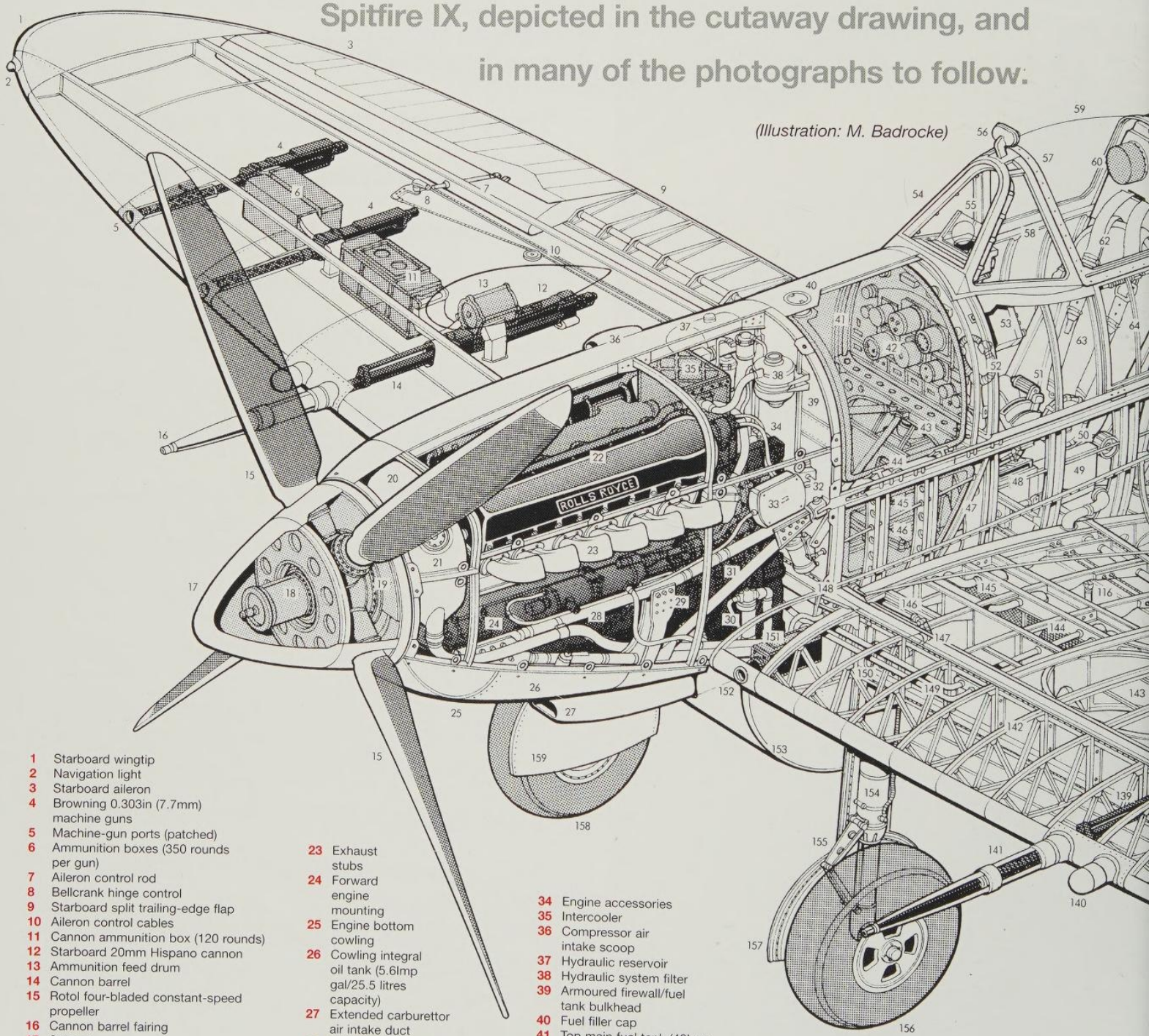
Restore to flight

The ultimate 'boy's toy' must surely be a Spitfire, and to those connoisseurs of fine aircraft the lifetime dream is to own and fly a Spit. To the majority of us this dream is beyond reach, not only because of the amount of money required to purchase a project but also because of the ensuing costs to restore it to flying state. However, there is no greater satisfaction than slowly restoring an aircraft piece by piece as if putting together a giant sized jigsaw. Each part of the aircraft requires assessing as to its viability, whether to restore, repair or replace. After these major decisions have been made it's down to sheer hard work and perseverance.

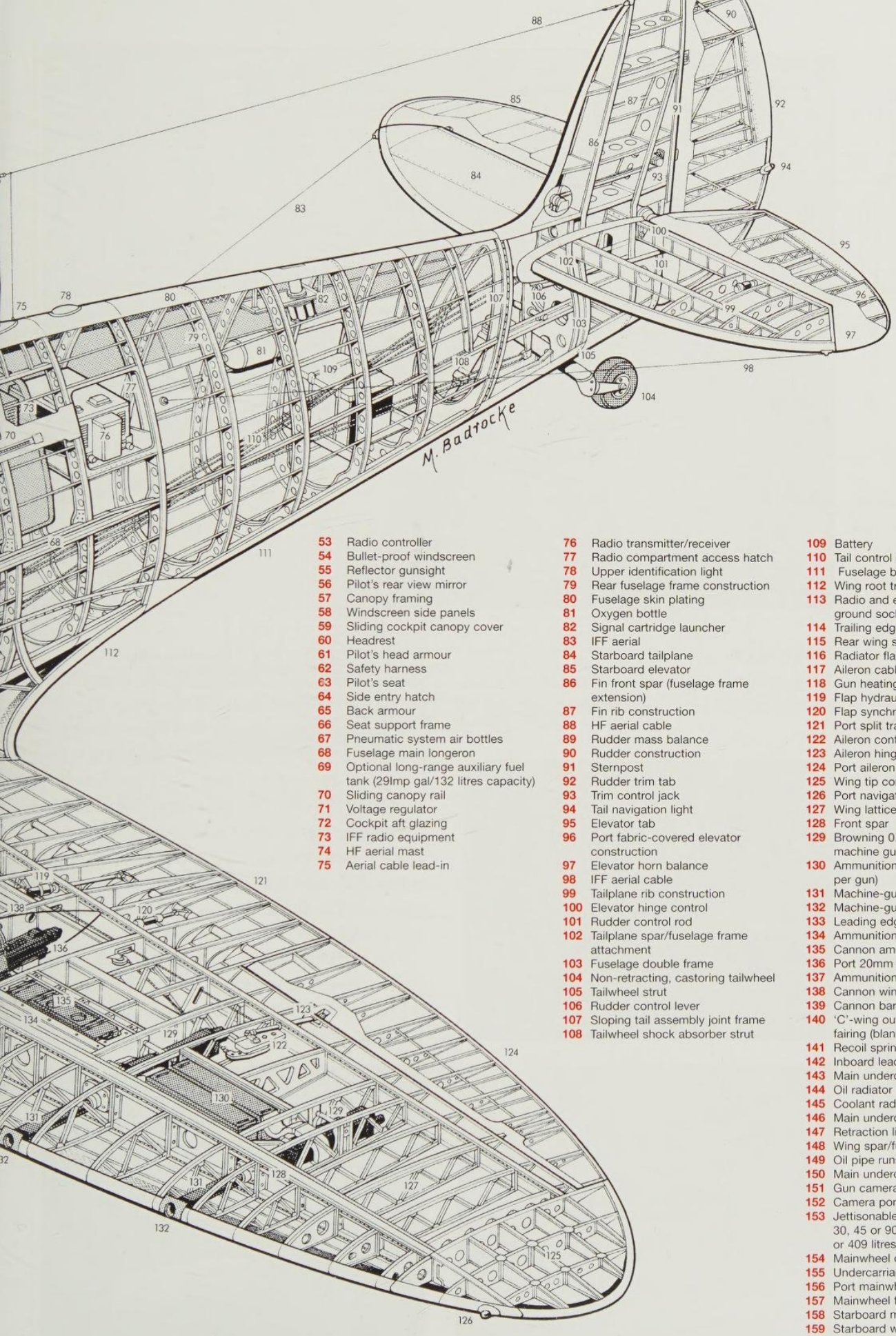
Anatomy of the Spitfire

This section describes primarily the structure of the high-backed Spitfire IX, depicted in the cutaway drawing, and in many of the photographs to follow.

(Illustration: M. Badrocke)



1 Starboard wingtip
2 Navigation light
3 Starboard aileron
4 Browning 0.303in (7.7mm) machine guns
5 Machine-gun ports (patched)
6 Ammunition boxes (350 rounds per gun)
7 Aileron control rod
8 Bellcrank hinge control
9 Starboard split trailing-edge flap
10 Aileron control cables
11 Cannon ammunition box (120 rounds)
12 Starboard 20mm Hispano cannon
13 Ammunition feed drum
14 Cannon barrel
15 Rotol four-bladed constant-speed propeller
16 Cannon barrel fairing
17 Spinner
18 Propeller hub pitch control mechanism
19 Armoured spinner
20 Cooling system header tank
21 Coolant filler cap
22 Rolls-Royce Merlin 61 liquid-cooled 12-cylinder Vee piston engine
23 Exhaust stubs
24 Forward engine mounting
25 Engine bottom cowling
26 Cowling integral oil tank (5.6Imp gal/25.5 litres capacity)
27 Extended carburettor air intake duct
28 Engine bearer struts
29 Main engine mounting member
30 Oil filter
31 Two-stage supercharger
32 Engine bearer attachment
33 Suppressor
34 Engine accessories
35 Intercooler
36 Compressor air intake scoop
37 Hydraulic reservoir
38 Hydraulic system filter
39 Armoured firewall/fuel tank bulkhead
40 Fuel filler cap
41 Top main fuel tank (48Imp gal/218 litres capacity)
42 Back of instrument panel
43 Compass mounting
44 Fuel tank/longeron attachment fitting
45 Bottom main fuel tank (37Imp gal/168 litres capacity)
46 Rudder pedal bar
47 Sloping fuel tank bulkhead
48 Fuel cock control
49 Chart case
50 Trim control handwheel
51 Engine throttle and propeller controls
52 Control column handgrip

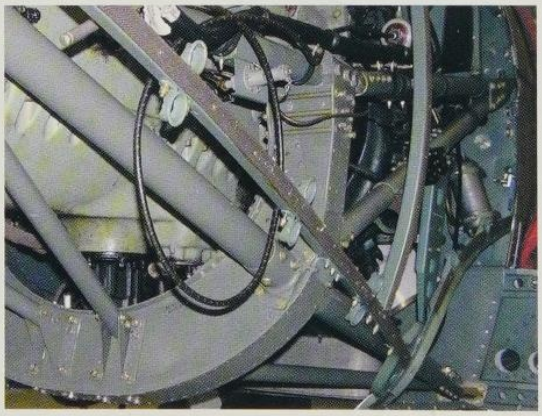


53 Radio controller
54 Bullet-proof windscreen
55 Reflector gunsight
56 Pilot's rear view mirror
57 Canopy framing
58 Windscreen side panels
59 Sliding cockpit canopy cover
60 Headrest
61 Pilot's head armour
62 Safety harness
63 Pilot's seat
64 Side entry hatch
65 Back armour
66 Seat support frame
67 Pneumatic system air bottles
68 Fuselage main longeron
69 Optional long-range auxiliary fuel tank (29Imp gal/132 litres capacity)
70 Sliding canopy rail
71 Voltage regulator
72 Cockpit aft glazing
73 IFF radio equipment
74 HF aerial mast
75 Aerial cable lead-in
76 Radio transmitter/receiver
77 Radio compartment access hatch
78 Upper identification light
79 Rear fuselage frame construction
80 Fuselage skin plating
81 Oxygen bottle
82 Signal cartridge launcher
83 IFF aerial
84 Starboard tailplane
85 Starboard elevator
86 Fin front spar (fuselage frame extension)
87 Fin rib construction
88 HF aerial cable
89 Rudder mass balance
90 Rudder construction
91 Sternpost
92 Rudder trim tab
93 Trim control jack
94 Tail navigation light
95 Elevator tab
96 Port fabric-covered elevator construction
97 Elevator horn balance
98 IFF aerial cable
99 Tailplane rib construction
100 Elevator hinge control
101 Rudder control rod
102 Tailplane spar/fuselage frame attachment
103 Fuselage double frame
104 Non-retracting, castoring tailwheel
105 Tailwheel strut
106 Rudder control lever
107 Sloping tail assembly joint frame
108 Tailwheel shock absorber strut
109 Battery
110 Tail control cable runs
111 Fuselage bottom longeron
112 Wing root trailing edge fillet
113 Radio and electrical system ground socket
114 Trailing edge flap shroud ribs
115 Rear wing spar
116 Radiator flap jack
117 Aileron cable runs
118 Gun heating air duct
119 Flap hydraulic jack
120 Flap synchronising jack
121 Port split trailing-edge flap
122 Aileron control bellcrank
123 Aileron hinge control rod
124 Port aileron construction
125 Wing tip construction
126 Port navigation light
127 Wing lattice rib construction
128 Front spar
129 Browning 0.303in (7.7mm) machine guns
130 Ammunition boxes (350 rounds per gun)
131 Machine-gun muzzle blast tubes
132 Machine-gun ports (patched)
133 Leading edge nose ribs
134 Ammunition box armour protection
135 Cannon ammunition box (120 rounds)
136 Port 20mm Hispano cannon
137 Ammunition feed drum
138 Cannon wing fairing
139 Cannon barrel
140 'C'-wing outboard cannon muzzle fairing (blanked-off)
141 Recoil spring
142 Inboard leading edge lattice ribs
143 Main undercarriage wheel well
144 Oil radiator
145 Coolant radiator
146 Main undercarriage retraction jack
147 Retraction link
148 Wing spar/fuselage attachment joint
149 Oil pipe runs to radiator
150 Main undercarriage leg pintle
151 Gun camera
152 Camera port
153 Jettisonable slipper tank, capacity 30, 45 or 90 Imp gal (136, 205 or 409 litres)
154 Mainwheel oleo damper
155 Undercarriage torque links
156 Port mainwheel
157 Mainwheel fairing door
158 Starboard mainwheel
159 Starboard wheel fairing door

RIGHT: The engine bearers of Mark XVI TE311, showing the U-frame and tubular members. *(P. Blackah/ Crown Copyright)*

Fuselage

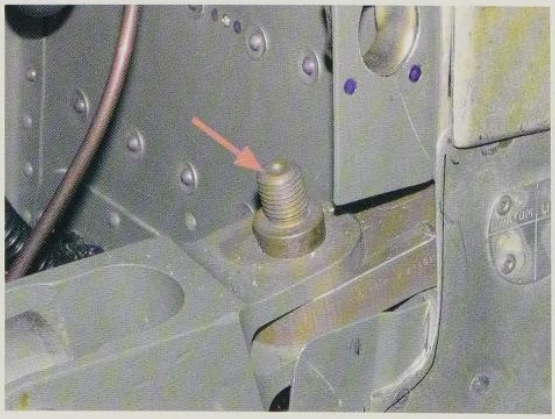
The fuselage comprises three main parts: the engine mounting, the main fuselage, and the tail unit.



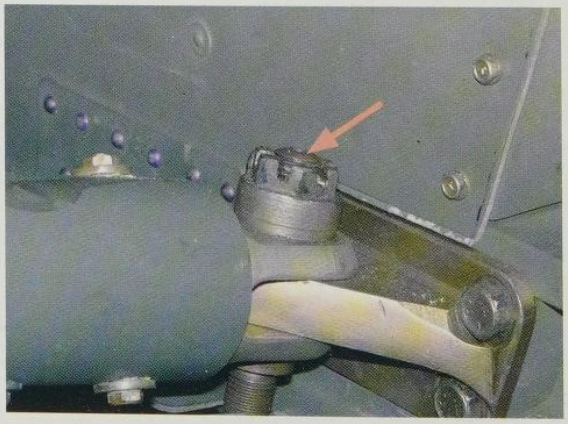
RIGHT: A close-up view of a Mark XVI U-frame and tubular members with the engine in situ. *(P. Blackah/Crown Copyright)*

The engine bearer is constructed with a U-shaped frame, with steel tubular members. The engine bearer is attached to Frame 5 of the fuselage by four large bolts. The main fuselage comprises an all-metal structure extending from the rear of the engine bearer to the joint just forward of the tail. The front frame, Frame 5, carries the pick-ups for the engine bearer and also the carry-through stub spars that attach to the wing main-spar booms. This frame also serves as a fireproof bulkhead between the rear of the engine and the fuel tanks.

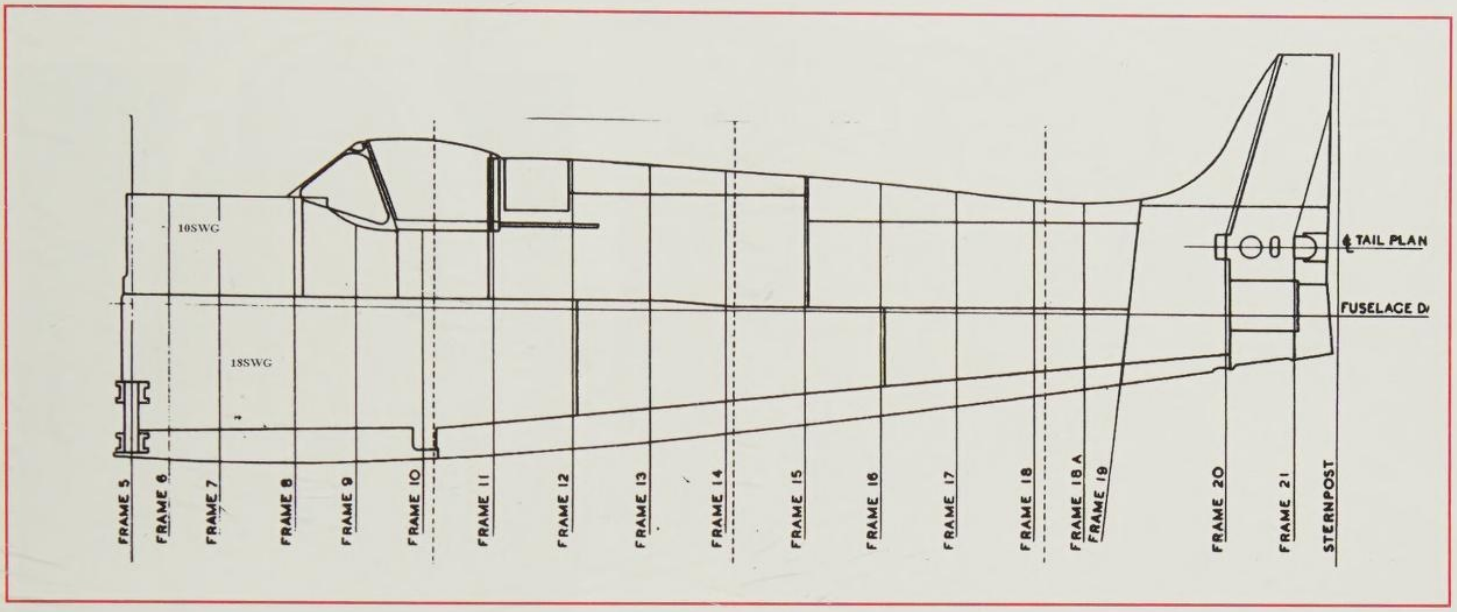
The main fuselage is made up from 15 frames running rearwards from Frame 5, back to Frame 19, where the tail section is attached. The main fuselage frames are attached to five

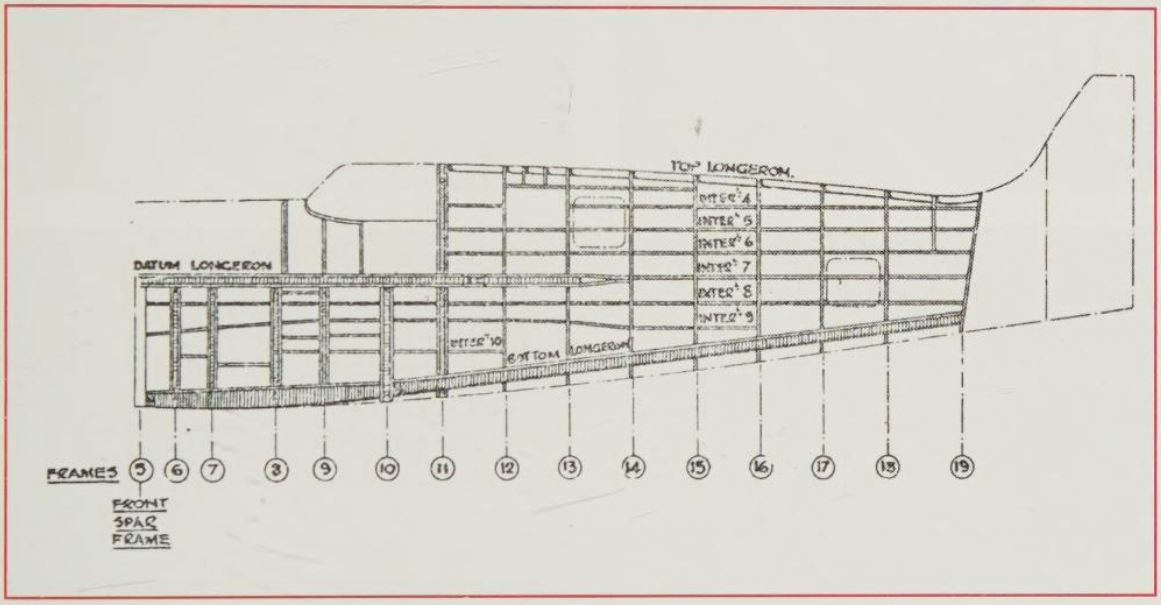


RIGHT: The top engine bearer-to-fuselage taper bolt (arrowed) on a Mark XVI... *(P. Blackah/Crown Copyright)*



FAR RIGHT: ...and a lower bolt (arrowed) – left-hand (port) bolts shown in both cases. *(P. Blackah/Crown Copyright)*

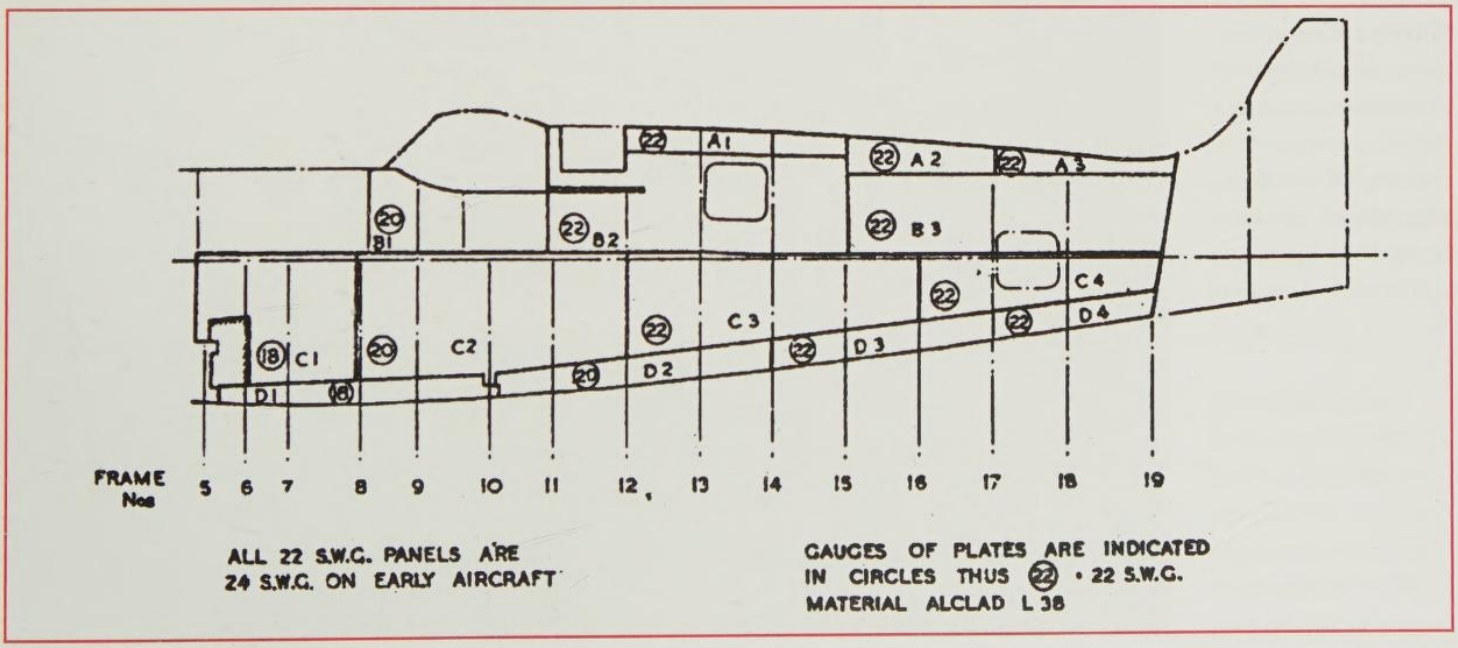


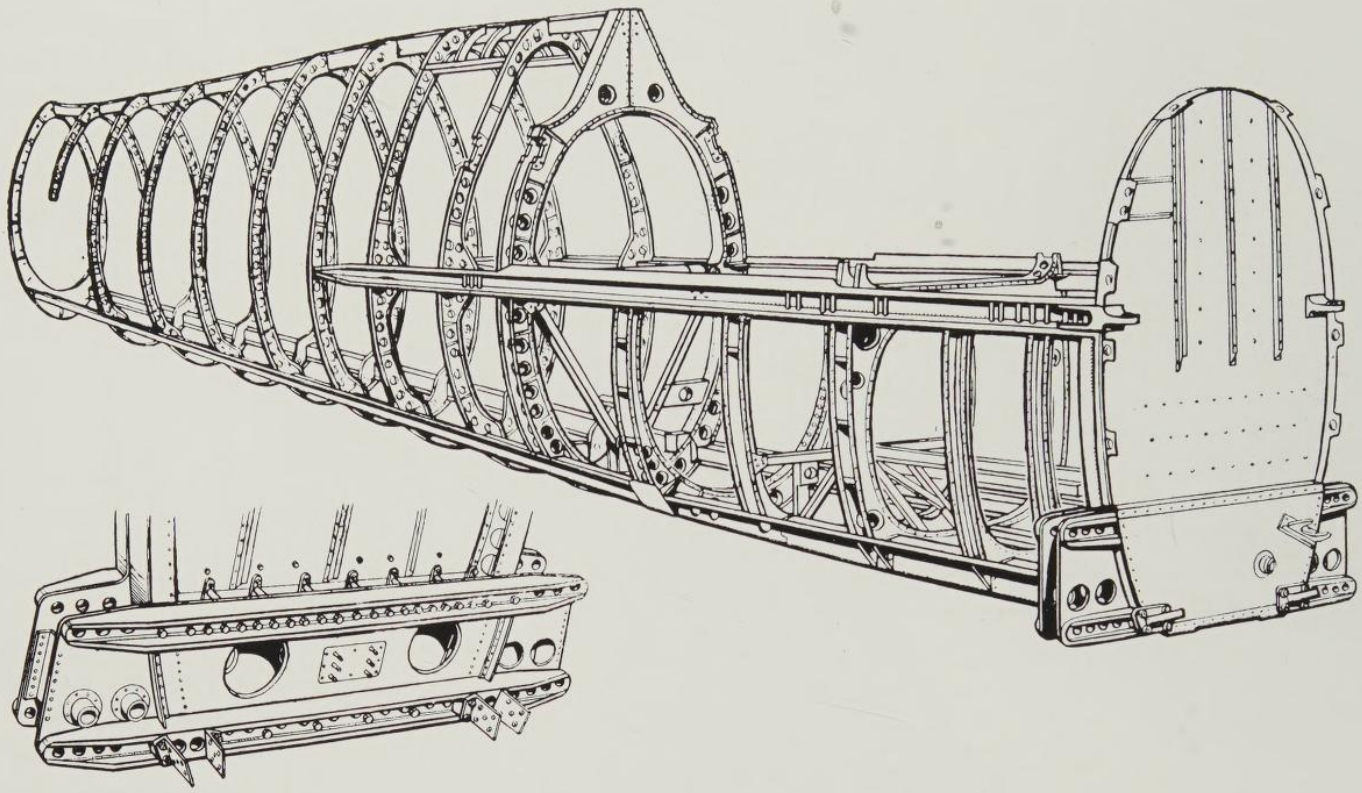


ABOVE: Drawings from Air Publication (AP) 1565 showing the fuselage frames from the engine bulkhead (Frame 5) to the fin (Sternpost)...

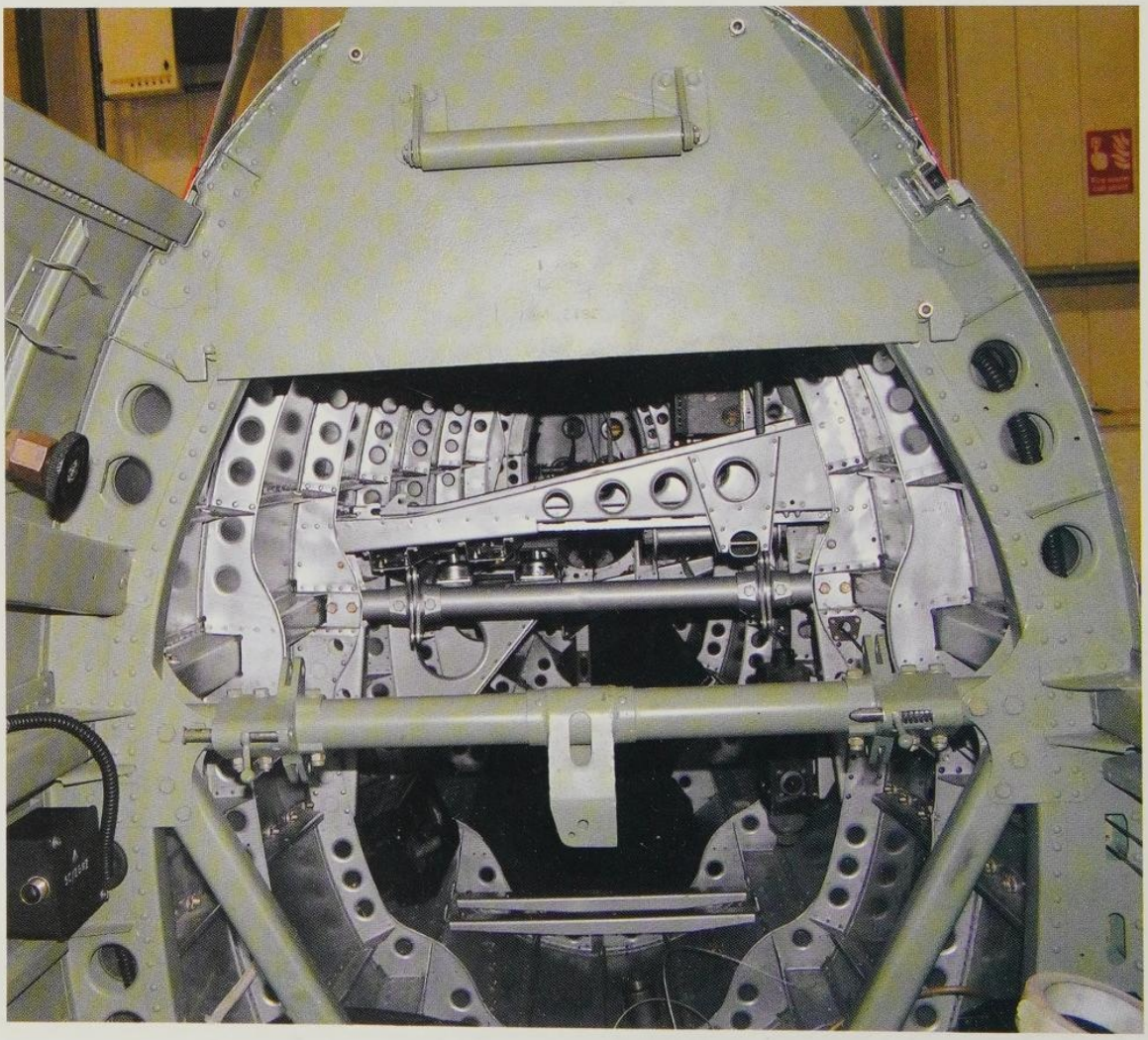
LEFT: ...the arrangement of the fuselage longerons and intercostals...

BELOW: ...and the thicknesses (in SWG) of the aluminium alloy panels. *(All Crown Copyright)*





ABOVE: A drawing showing the structure of the main fuselage section. Inset is a rear view of the lower part of Frame 5, showing the stub spars to which the wings attach. *(Crown Copyright)*



RIGHT: Looking back along the fuselage of TE311 from the cockpit (Frame 11), showing the internal structure. *(P. Blackah/ Crown Copyright)*

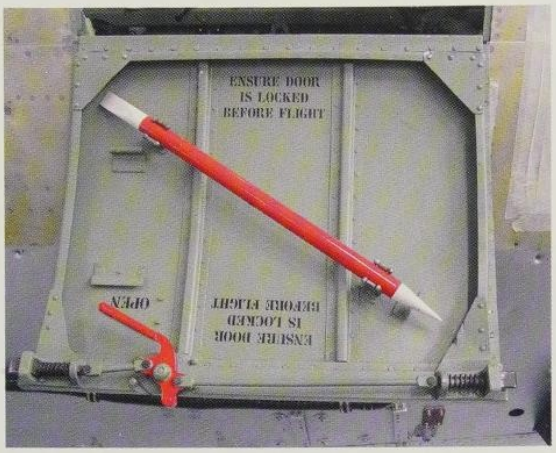
longerons, the top, two datum and two bottom. Linking the frames together are the intercostals. The resultant framework is clad with overlapping aluminium alloy panels riveted into place. These panels vary in thickness from 18 SWG (standard wire gauge, 1.2mm thick) at the forward end of the fuselage, to 22 SWG (0.7mm) at the aft end.

The cockpit fits between Frames 8 and 11, and has a rearwards-sliding canopy that can be jettisoned in an emergency. A hinged panel in the port (left) side of the cockpit assists entry and exit. A thick slab of laminated glass on the front of the windscreen shields the pilot from rifle-calibre rounds coming from ahead. Behind

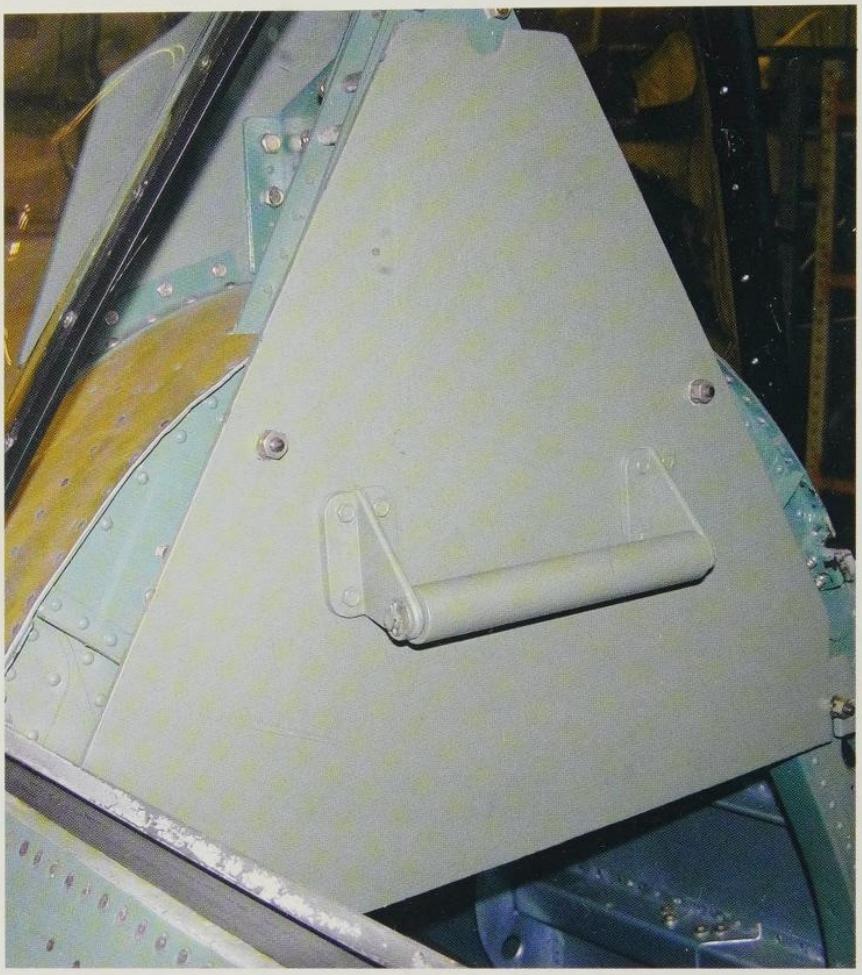
TOP LEFT: Looking forward along the fuselage of Mark XVI TE311 from Frame 19. The small (2BA) bolts which secure the tail unit in place fit through the small holes around the edge of Frame 19. *(P. Blackah/Crown Copyright)*

ABOVE: Pete Glow of Airframe Assemblies, working at a jig to produce a Spitfire XI fuselage. The company has three such jigs in operation. *(Alfred Price Collection)*

LEFT: Restoration of Mark IX MK356 nearing completion, showing the cockpit access door open on the port side of the cockpit. *(Paul Harrison)*

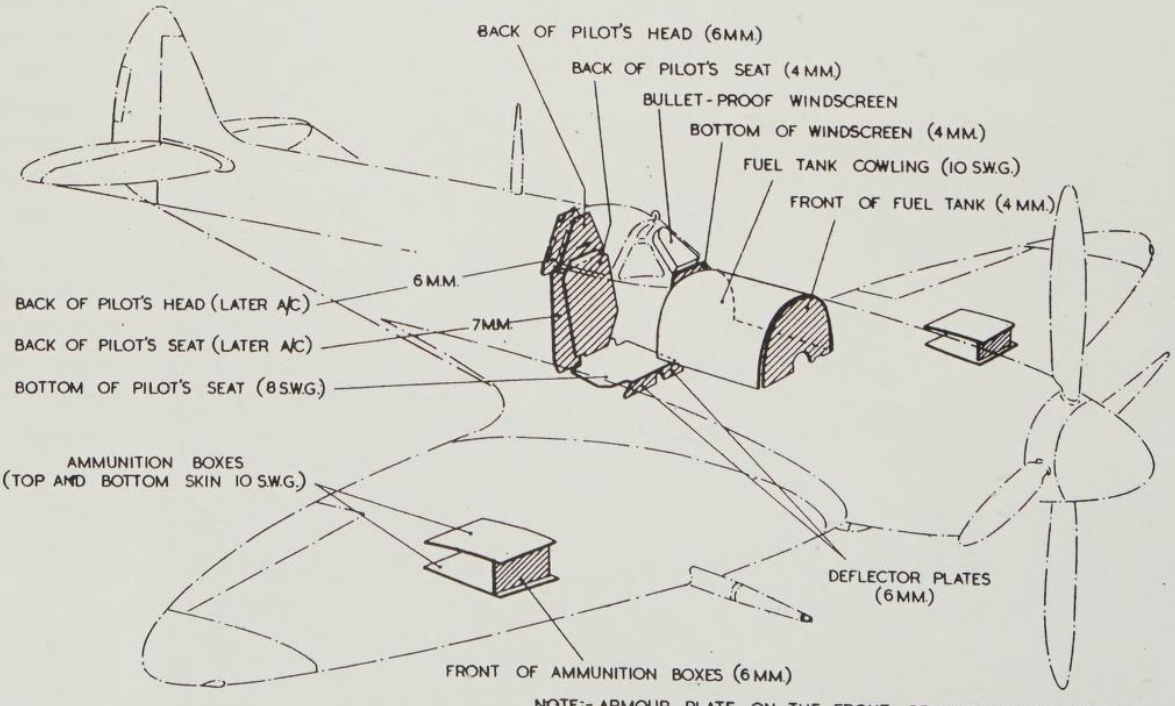


ABOVE: Cockpit access door open, showing the operating handle and the crowbar for use in an emergency should the canopy fail to open.
(P. Blackah/Crown Copyright)



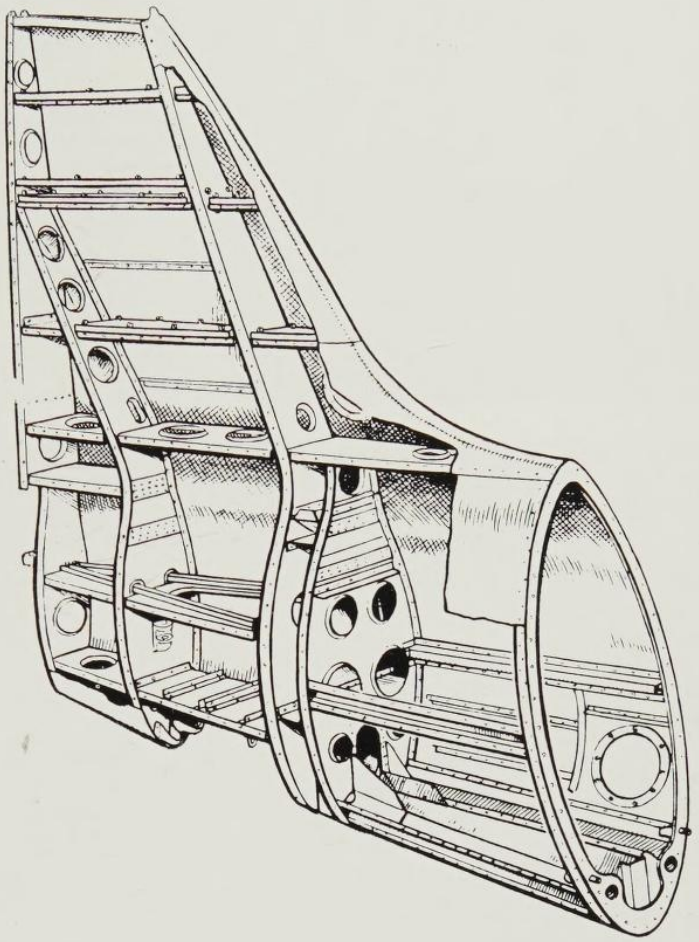
ABOVE RIGHT: The head armour fitted to Mark XVI TE311. The roller is for the pilot's harness, which is routed up behind and over it.
(P. Blackah/Crown Copyright)

BELOW: A drawing showing details of the armour plating fitted to a typical wartime Spitfire.*(Crown Copyright)*


BACK OF PILOT'S HEAD (6 MM.)
BACK OF PILOT'S SEAT (4 MM.)
BULLET-PROOF WINDSCREEN
BOTTOM OF WINDSCREEN (4 MM.)
FUEL TANK COWLING (10 S.W.G.)
FRONT OF FUEL TANK (4 MM.)
6 MM.
7 MM.
BACK OF PILOT'S HEAD (LATER A/C)
BACK OF PILOT'S SEAT (LATER A/C)
BOTTOM OF PILOT'S SEAT (8 S.W.G.)
AMMUNITION BOXES
(TOP AND BOTTOM SKIN 10 S.W.G.)
DEFLECTOR PLATES
(6 MM.)
FRONT OF AMMUNITION BOXES (6 MM.)
ARMOUR PLATE, THICKNESS IN MILLIMETRES.
LIGHT-ALLOY. STANDARD WIRE GAUGE.
NOTE:- ARMOUR PLATE ON THE FRONT OF AMMUNITION BOXES DELETED WHEN THE EXTRA PROTECTION BEHIND PILOT'S SEAT ON LATER AIRCRAFT IS EMBODIED

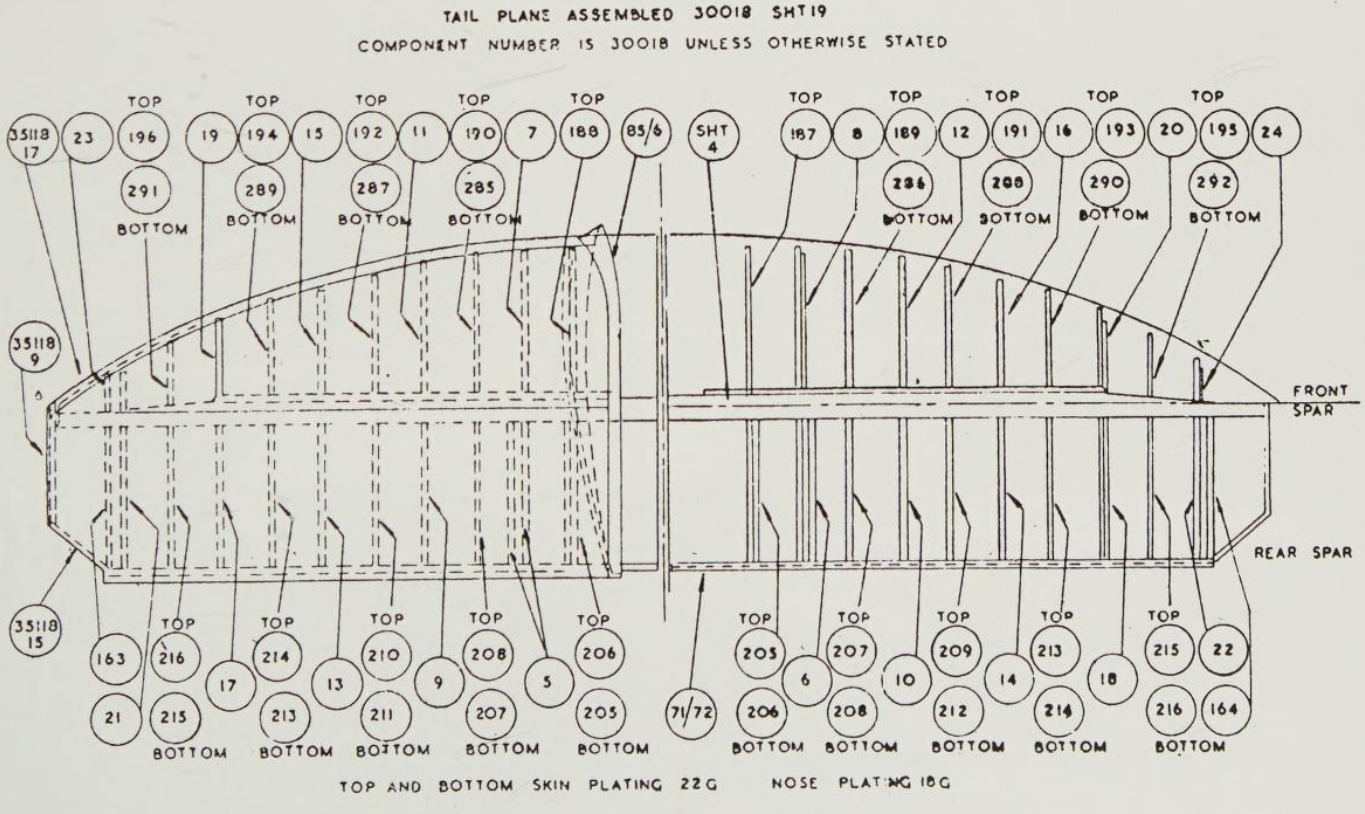
and below the pilot's seat is 73lb of steel plating, arranged to protect his head and back from rounds fired from behind or below.

The tail section, which includes the fin, is made up of frames and ribs skinned with 24 SWG (0.6mm) aluminium panels. The tail section is joined to the fuselage at Frame 19 by 50 small (2 BA) bolts and by four ¼in BSF studs and nuts. The tailplane is built in two halves, port and starboard. It is built around two spars, one forward and one to the rear, and a series of ribs. These structures are skinned with aluminium alloy. The tailplanes are fitted to the tail section with close-tolerance bolts. The elevators and rudder are made up from a D-section spar and various frames, and are covered with Irish linen.



RIGHT: A drawing showing the structure of the tail unit. Note how two of the rear frames extend upwards to form the integral fin. *(Crown Copyright)*

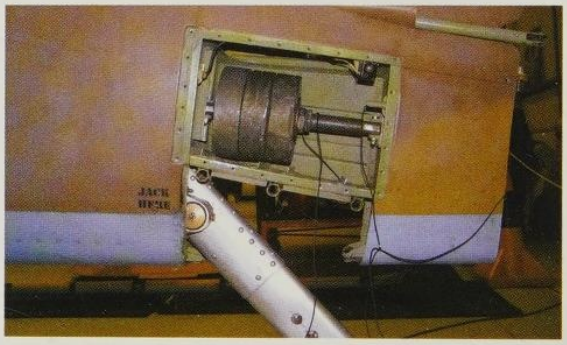
BELOW: A drawing showing the construction of the assembled tailplane. *(Crown Copyright)*


TAIL PLANE ASSEMBLED 30018 SHT 19
COMPONENT NUMBER IS 30018 UNLESS OTHERWISE STATED
FRONT SPAR
REAR SPAR
TOP AND BOTTOM SKIN PLATING 22G
NOSE PLATING 18G

LEFT: The rudder of Mark XVI TE311, showing the internal structure before covering. *(P. Blackah/ Crown Copyright)*

MIDDLE: The finished fabric-covered rudder on TE311. Applying the fabric covering to the rudder and elevator requires specialist skills, and the task was carried out by Vintage Fabrics based near Colchester. *(P. Blackah/Crown Copyright)*

BELOW: With several items of wartime operational equipment removed, an average Spitfire today weighs around 25% less than it would have done in 'battle' trim. To restore the aircraft's centre of gravity to within the correct limits, lead rings (seen here on Mark V AB910) can be fitted in the ballast compartment in the rear fuselage. *(P. Blackah/Crown Copyright)*



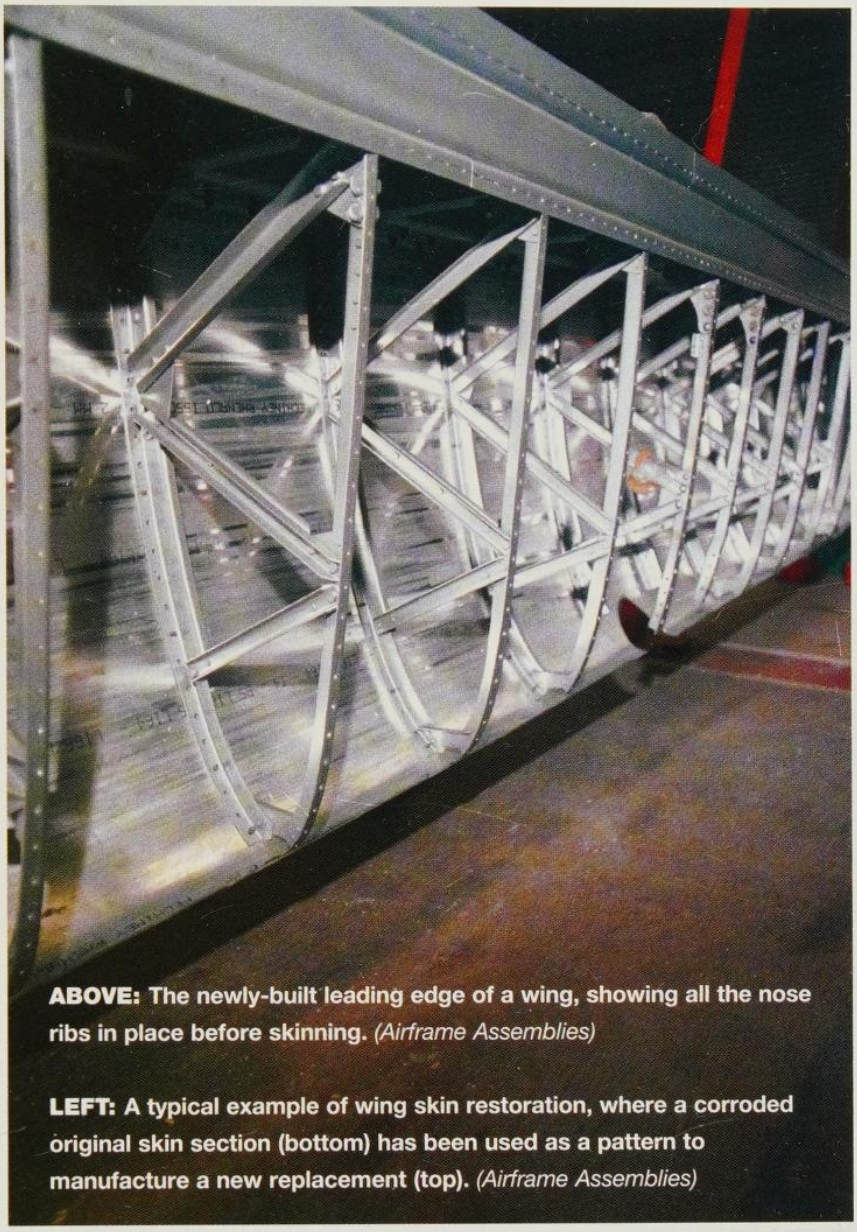
Seamstresses hard at work in the fabric shop at the Castle Bromwich factory circa 1944, covering Spitfire rudders. *(Vickers)*

Wings ('main-planes')

The wings are all-metal cantilever structures, elliptical in plan and tapering in thickness. Each wing comprises a leading edge D-spar, a rear auxiliary spar and 21 ribs attached to both the D-spar and the auxiliary spar.

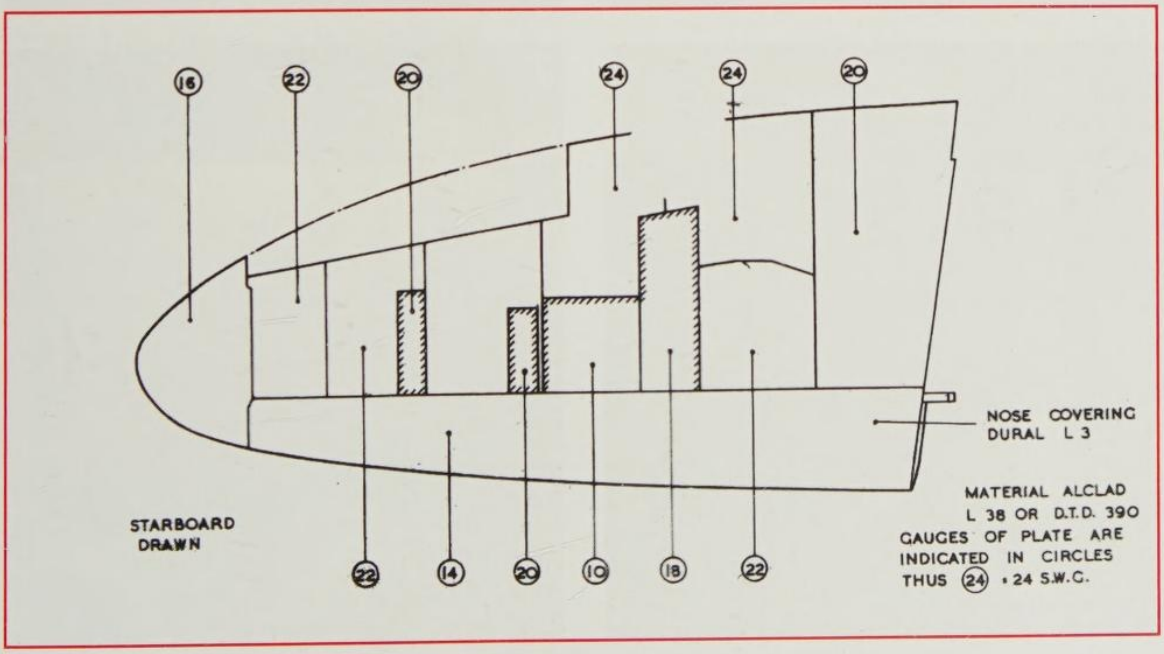
The front spar, comprising the upper and lower booms and the spar web, together with the thick skin of the wing leading edge, combine to form a D-shaped box structure light in weight but with great strength. Stiffening members are fitted at various points such as the wheel wells and the gun bays. The framework is covered with aluminium alloy sheet, in thicknesses ranging from 14 SWG (2mm) at the leading edge to 24 SWG (0.6mm) on the wing itself.

Each wing is attached to the fuselage by seven large bolts. These go through the upper



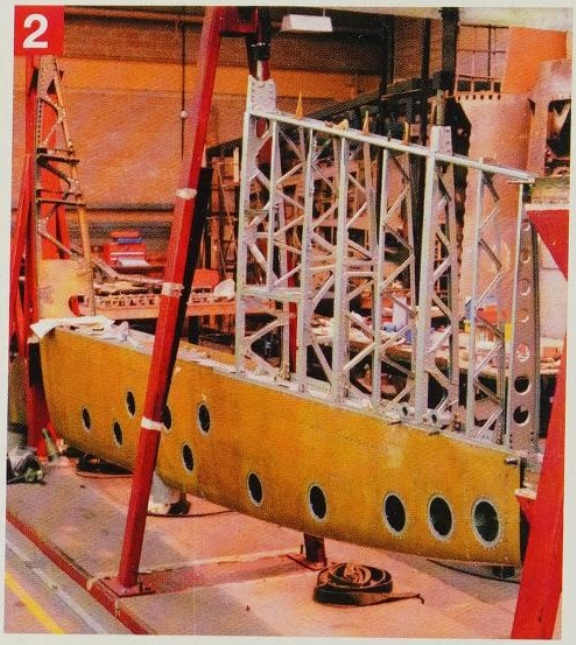
ABOVE: The newly-built leading edge of a wing, showing all the nose ribs in place before skinning. *(Airframe Assemblies)*

LEFT: A typical example of wing skin restoration, where a corroded original skin section (bottom) has been used as a pattern to manufacture a new replacement (top). *(Airframe Assemblies)*



LEFT: Wing skin thicknesses (in SWG), as stipulated by AP1565. *(Crown Copyright)*

1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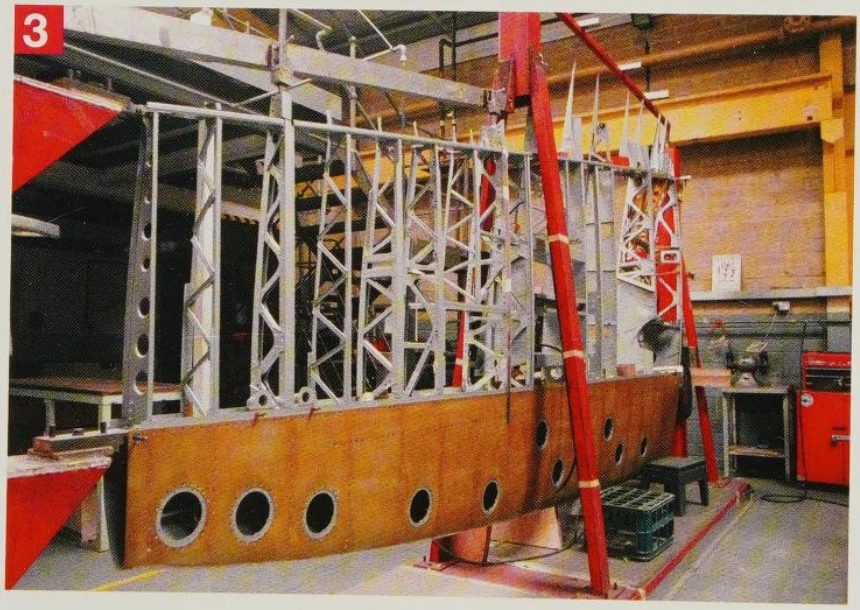
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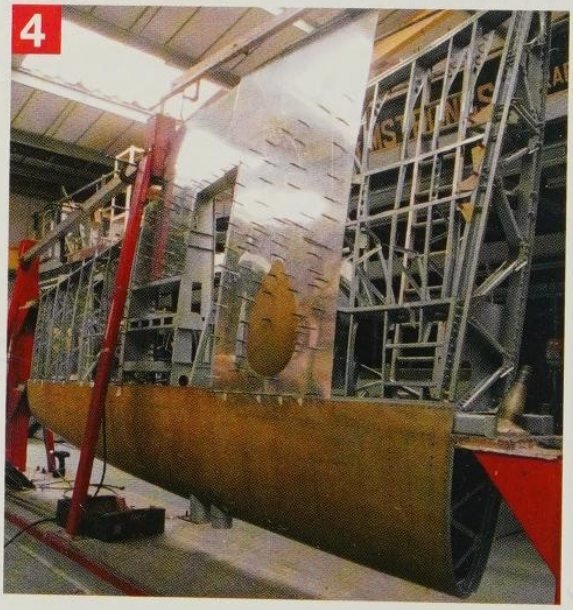
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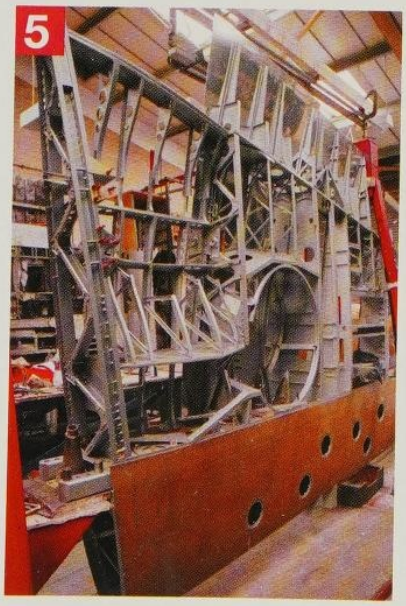
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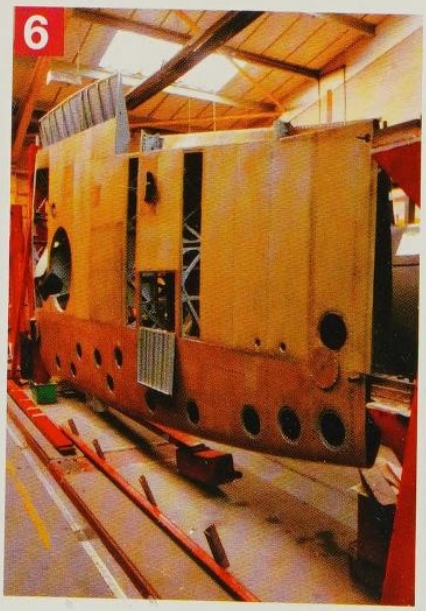
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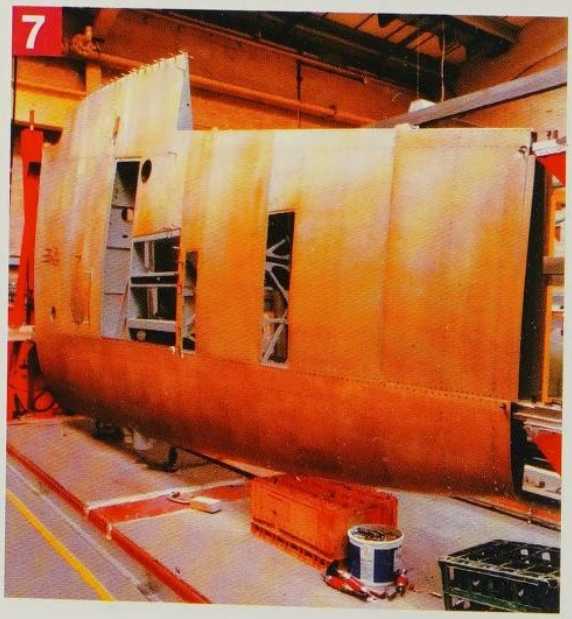

7

1 A port wing, stripped of most of the skinning on the underside to expose the frames and ribs, awaiting refurbishment. *(Airframe Assemblies)*

2 With the leading edge D-shaped box structure complete, the outboard frames are then attached – starboard wing shown. *(Airframe Assemblies)*

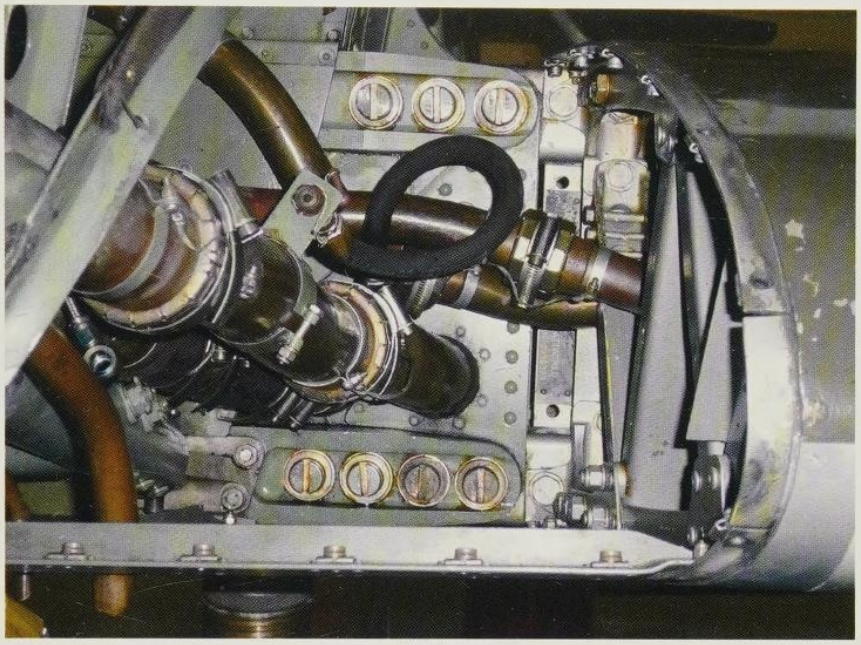
3 A view of the underside of the wing, with all the frames now in place, prior to skinning – port wing shown. *(Airframe Assemblies)*

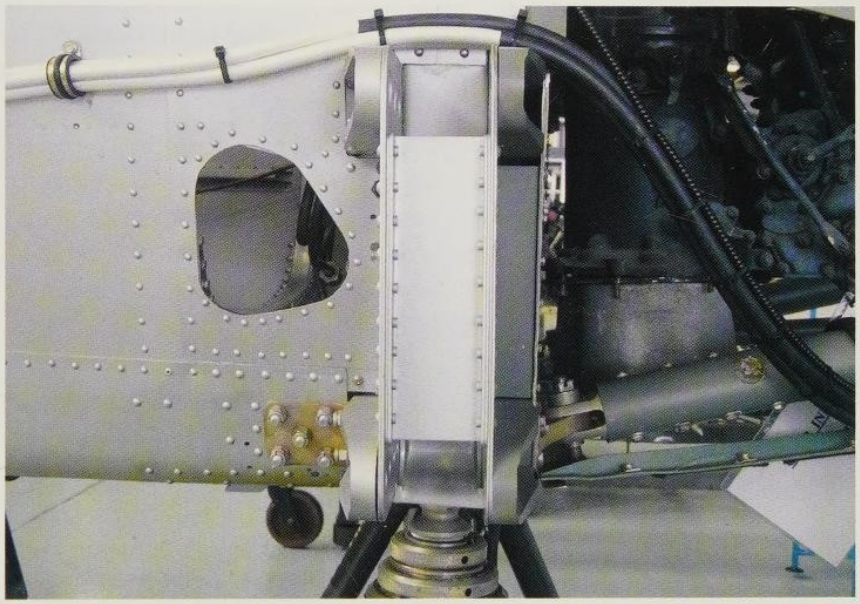
4 Here, the aluminium alloy skins are being fitted to the top surface of the wing – starboard wing shown. *(Airframe Assemblies)*

5 An underside view of the starboard wing, prior to skinning, showing the structure of the undercarriage bay. *(Airframe Assemblies)*

6 With the lower skins now fitted to the starboard wing, the flap shroud (top left) and the undercarriage and gun bay housings can be seen. *(Airframe Assemblies)*

7 With the upper skins fitted to the starboard wing, the gun and ammunition bay cover panels and the aileron have yet to be fitted. *(Airframe Assemblies)*

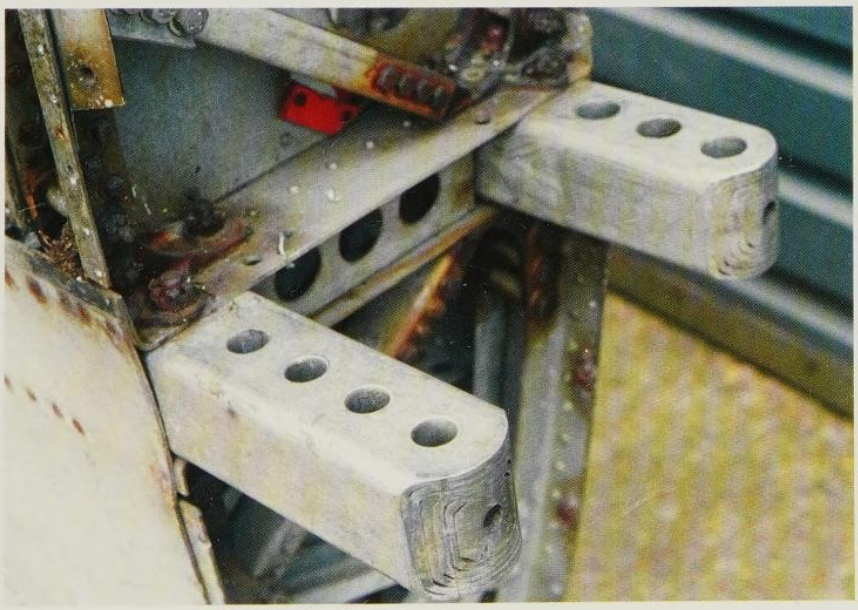


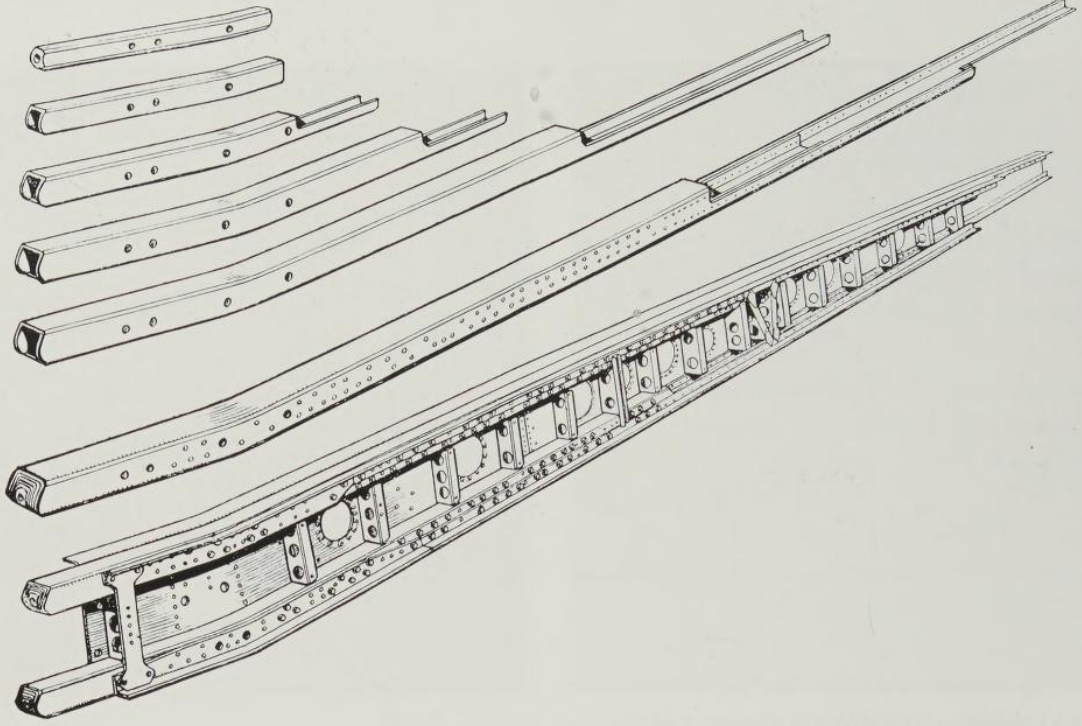


RIGHT TOP: Wing root of Mark IX MK356, showing the seven bolts, three upper and four lower, which hold the wing in place. *(P. Blackah/Crown Copyright)*

RIGHT MIDDLE: A side view of the wing stub spars attached to fuselage Frame 5, without the wings fitted. The wing spars slide into position between the stub spars and are secured by the bolts shown in the previous photograph. *(P. Blackah/Crown Copyright)*

RIGHT BOTTOM: A wing awaiting restoration, showing the ends of the spar booms which attach to the stub spars on the fuselage. The bolt holes (three upper and four lower) can be seen in the spars. *(P. Blackah/Crown Copyright)*



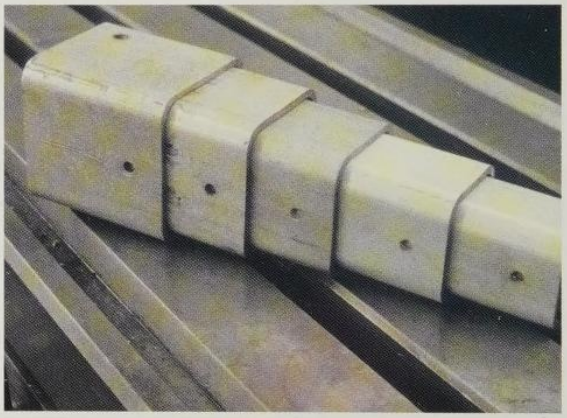


RIGHT: A drawing showing the wing spar construction. The lower view shows how the upper and lower spar booms are braced by the spar web that runs the full length of the wing, from root to tip. The upper views show how each spar boom is made up of concentric tubes, making it progressively stronger as it runs from the wing tip to the root. *(Crown Copyright)*

and lower spar booms, joining it to the carry-through stub spars on Frame 5 of the fuselage. An additional large bolt secures the rear spar.

The method of construction of the main wing spar booms is unusual. Each spar boom is built up from five square-section concentric tubes made of 11 SWG (4mm) aluminium alloy and one square section central plug. The tubes are made to fine tolerances, and fit tightly into each other. At the wing root the spar booms are made up of five thicknesses of tube, but as the loads on the spar decrease progressively towards the wing tip, so the inner tubes terminate one-by-one, until at the wing tip only the two outer thicknesses of tube remain.

BELOW: Short sections cut from each wing spar section to show how each spar boom is made up from concentric tubes. *(Airframe Assemblies)*



RIGHT: Aluminium alloy extrusions, ready to be brought together to produce Spitfire main spar booms. Eights sets of extrusions are shown here – sufficient to produce spar booms for two Spitfires (two booms per wing, four per aircraft). *(Airframe Assemblies)*

Aft of the main spar, the thinner gauge light alloy covering is supported by light alloy girder ribs to which the split flaps and the ailerons are attached. The split flaps, the ailerons and the detachable wing tips are all metal-covered.

ABOVE LEFT: A wing rib assembly, with aileron hinge fitting in unrestored (top) and restored (bottom) condition. *(Airframe Assemblies)*

ABOVE RIGHT: An example of a badly damaged wing tip prior to restoration. *(Airframe Assemblies)*

During restoration of assemblies such as this wing tip, as much use as possible is made of the original components. Where new components have to be fabricated, the original parts are used as templates. *(Airframe Assemblies)*

ABOVE: SAC Percival of the BBMF fits a wheel to an early type main undercarriage oleo with an internal spline assembly. *(P. Blackah/Crown Copyright)*

ABOVE RIGHT: A later type main undercarriage oleo with forward external torque-link assembly. Note the creep marks (arrowed) on the wheel and tyre, which show whether the tyre has moved on the wheel. *(P. Blackah/Crown Copyright)*

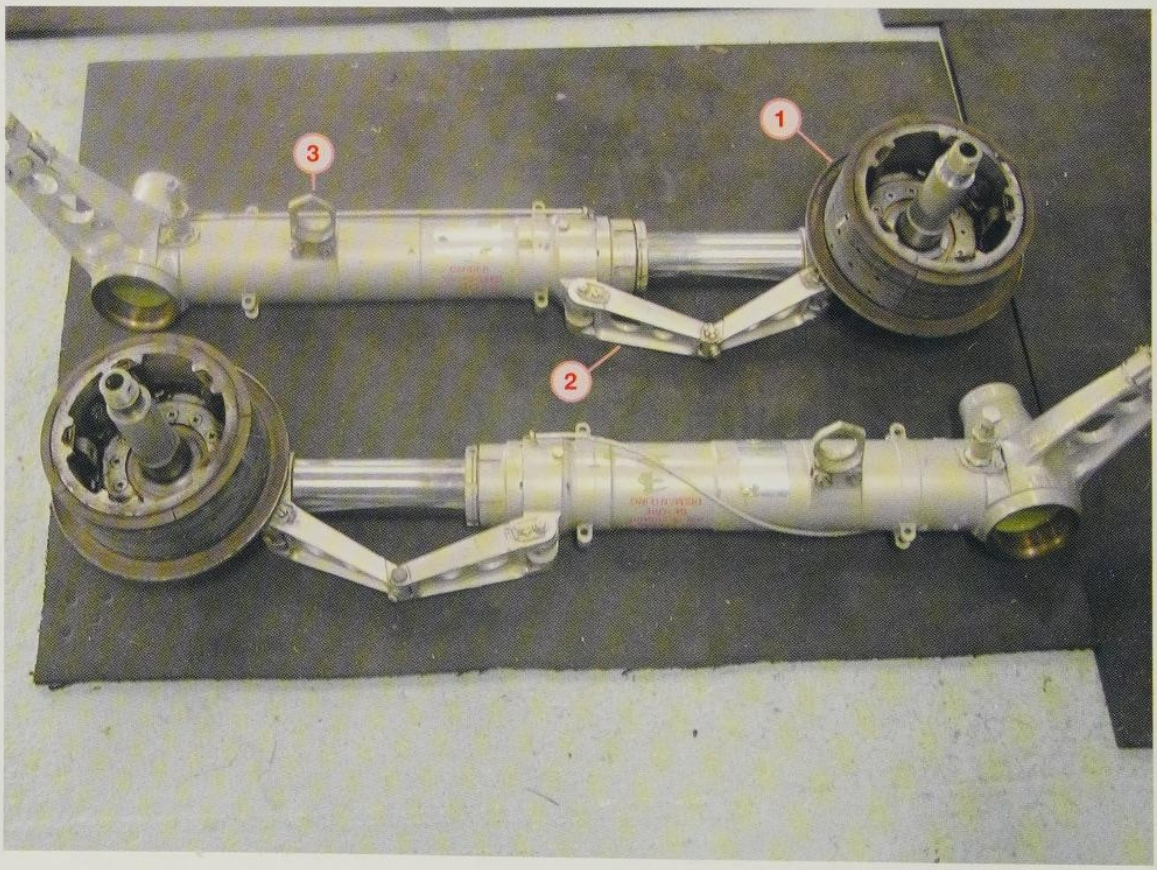
RIGHT: Later type main undercarriage oleos on the bench ready for servicing. The brake linings (1), torque-link assembly (2) and undercarriage 'up' locking eye (3) are clearly visible. *(P. Blackah/Crown Copyright)*

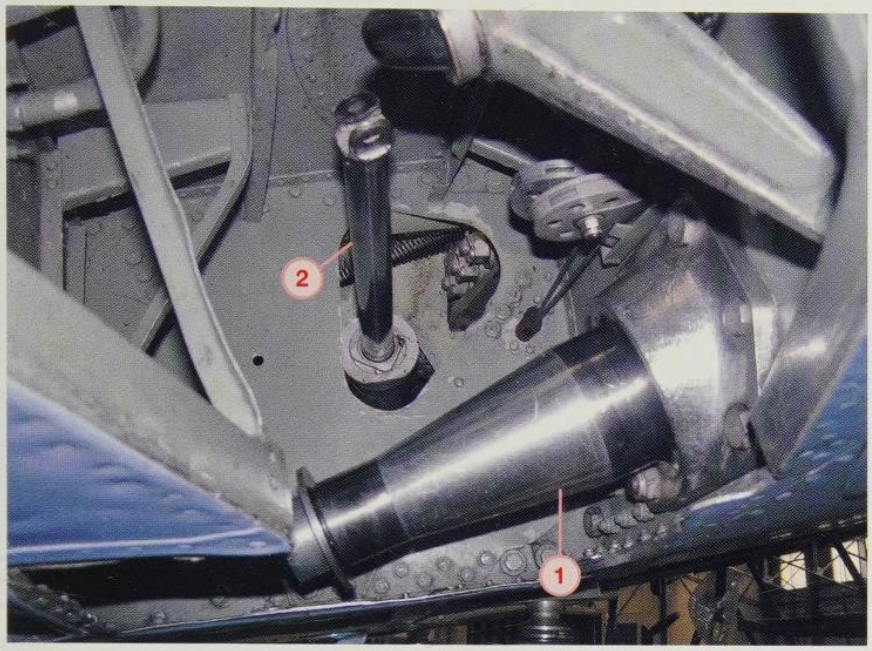
Undercarriage

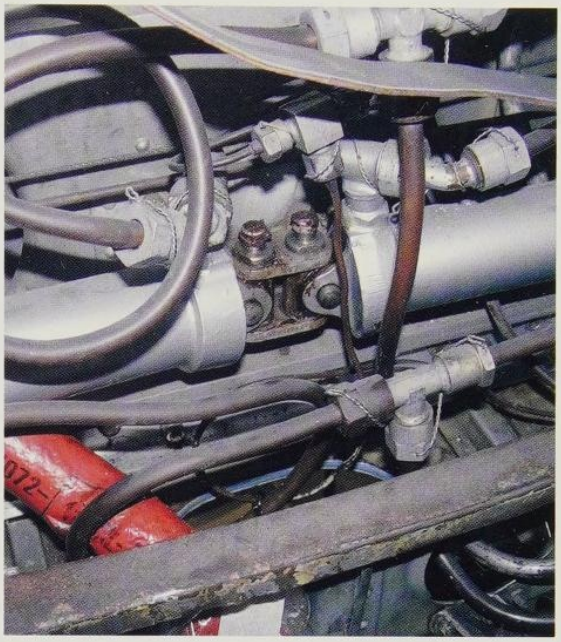
The undercarriage consists of two retractable main oleos (undercarriage legs) and a non-retractable tail leg. The main wheels are mounted on the main oleo legs, which have integral dampers (shock absorbers) both filled with oil and pressurised with nitrogen. There are two types of oleos, one with an internal spline assembly and one with an external torque link assembly.

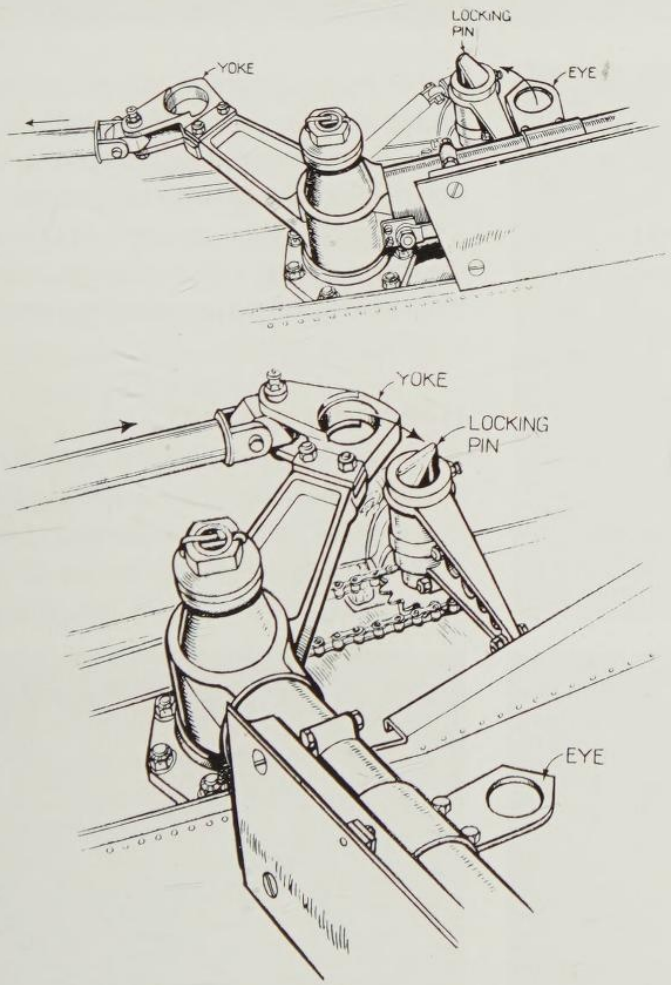
The main undercarriage oleos are attached to the airframe on pintle assemblies, which are mounted on the rear face of the wing main spars, just outboard of the wing-to-fuselage joints. Each oleo has a hydraulic retraction jack, which is mounted on the rear of fuselage Frame 5, and acts on a yoke on the oleo to rotate the oleo around the pintle.

The tail-wheel leg is swivel-mounted on tail







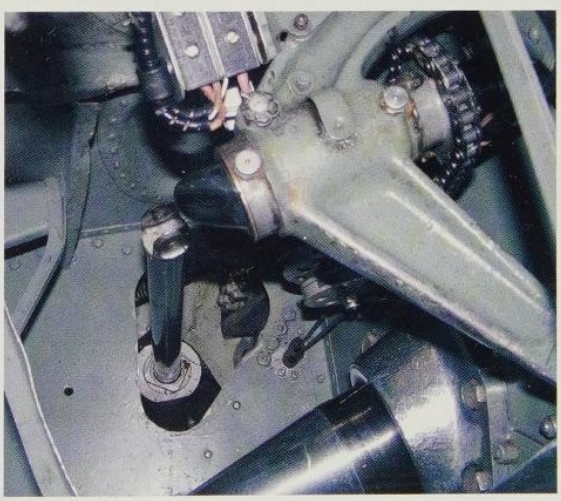


Undercarriage locking mechanism. The top view shows the oleo about to be locked in the 'up' position – the lug on the oleo engages with a spring-loaded locking pin on the spar. In the bottom view the oleo is approaching the 'down' position – the locking pin has rotated through 180° with its chamfered edge turned towards the eye on the leg. *(Crown Copyright)*

ABOVE LEFT: A view inside the undercarriage bay, with the oleo leg removed, showing the pintle assembly (1) over which the oleo fits and the end of the retraction jack (2) protruding through the fuselage into the wing. *(P. Blackah/ Crown Copyright)*

ABOVE RIGHT: A view showing the undercarriage retraction jacks fitted in the fuel tank bay to a bracket attached to fuselage Frame 5. The jacks pass through the fuselage into the wings, where they attach to the oleos (see previous photograph). *(P. Blackah/Crown Copyright)*

BELOW: A close-up view of the undercarriage locking mechanism with the oleo removed. The mechanism is cable- and chain-operated by means of the undercarriage selector in the cockpit. *(P. Blackah/Crown Copyright)*



ABOVE LEFT: A view looking back into the tail, showing the tail-wheel oleo and the tail leg strut assembly. The elevator (left) and rudder (right) control cables run on either side of the strut. *(P. Blackah/Crown Copyright)*

ABOVE RIGHT: The tail-wheel castering yoke assembly, complete with wheel, fitted to the end of the tail leg. *(P. Blackah/Crown Copyright)*

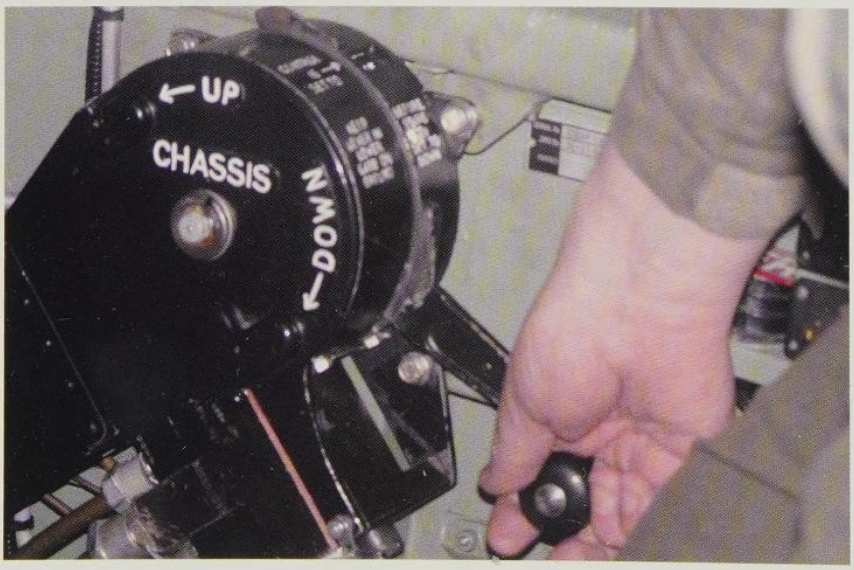
BELOW LEFT: When the undercarriage selector is moved to the 'down' position, the hydraulic pressure pushes the oleos off the locking pins, allowing the retraction jacks to push the oleos down until they lock. *(P. Blackah/Crown Copyright)*

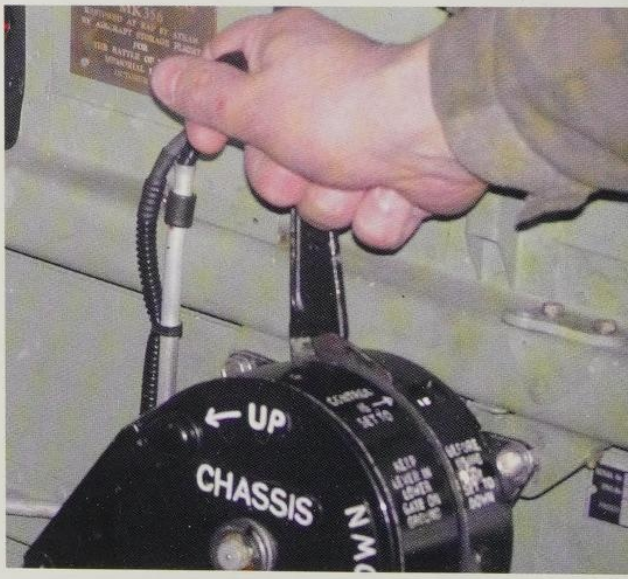
BELOW RIGHT: When the undercarriage selector is moved to the 'up' position the oleos move up under hydraulic pressure until they lock in the 'up' position. *(P. Blackah/Crown Copyright)*

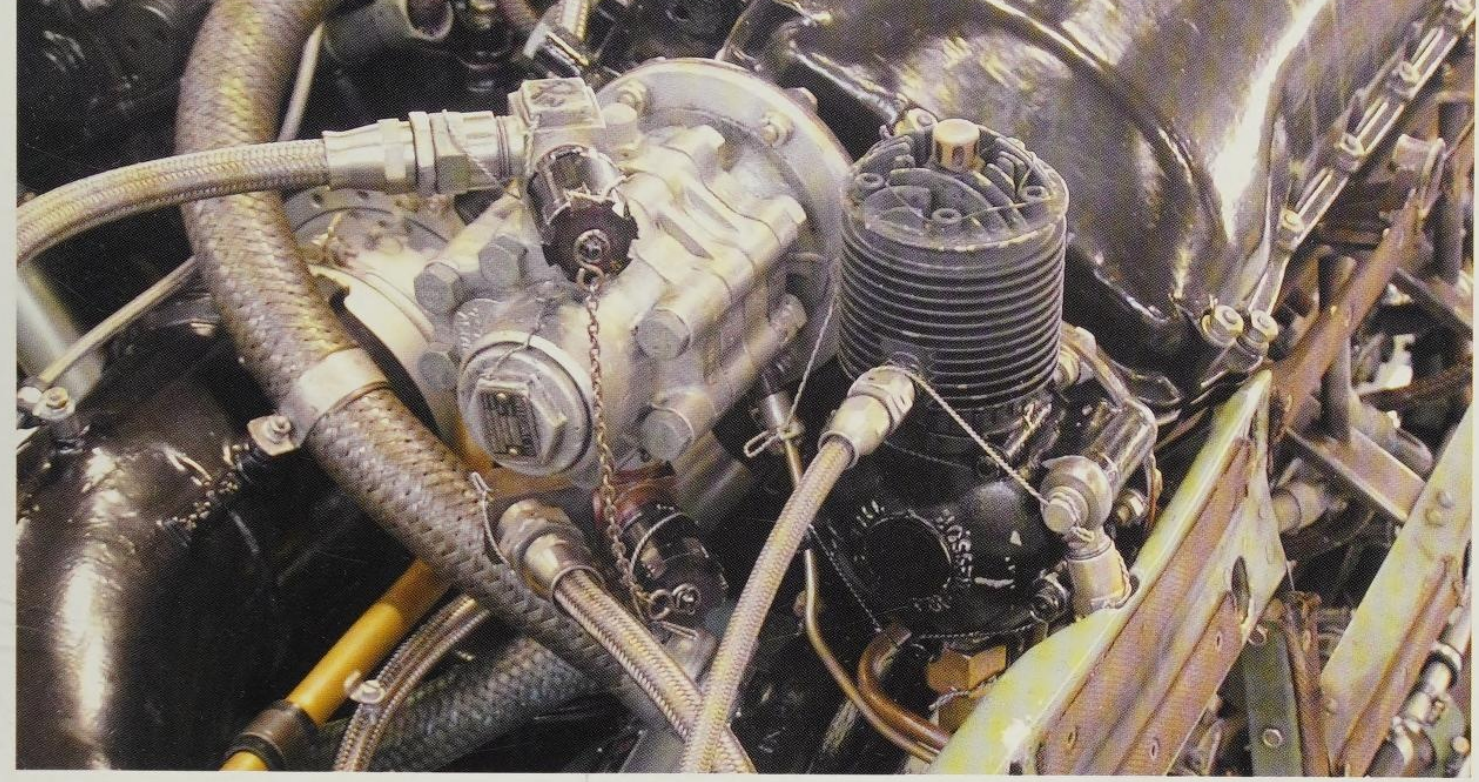
section Frame 20, and is attached to a damper strut mounted on Frame 19. As with the main oleos, the strut is filled with oil and pressurised with nitrogen. The tail wheel is attached to a fully castering yoke assembly mounted on the end of the leg. A friction washer between the yoke and the leg prevents the wheel from castering too violently.

Hydraulic system

The simple hydraulic system is used to raise and lower the undercarriage, and is controlled by a selector valve on the right side of the cockpit. The system is powered by an engine-driven pump mounted on the rear of the





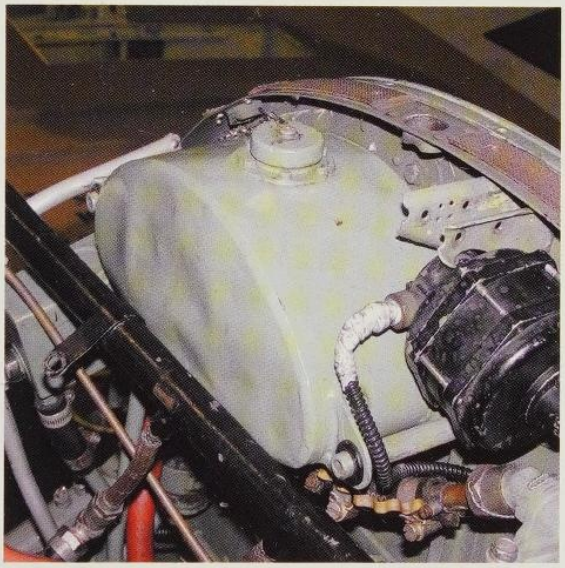


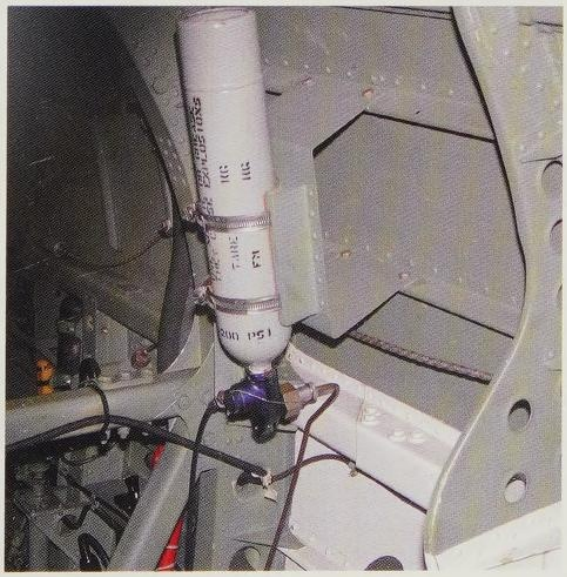
starboard cylinder block of the engine. A small hydraulic reservoir, pressure relief valve and filter assembly are mounted on the forward face of main fuselage Frame 5.

In the event of hydraulic failure there is a back-up emergency system to lower the main wheels. Originally, Spitfires were fitted with a small bottle of compressed carbon dioxide, located behind the undercarriage selector, on the starboard side of the cockpit. This had a red operating handle with the words 'emergency only' engraved on it, and was a 'one-shot' device to lower the main wheels using a system that sent pressurised gas to the retraction jacks, enabling the oleos to lock fully down. In most Spitfires currently flying the bottle is fitted for authenticity, but is not used. The red handle is attached to a cable that operates a modern air bottle located behind main fuselage Frame 11. The modern system operates in a similar manner to the original, but is easier to recharge.

Pneumatic system

The pneumatic system operates the wheel brakes and flaps. On original Spitfires it also cocked and fired the guns. The system is supplied with compressed air by two cylinders, located behind main fuselage Frame 11 on 'high-back' Spitfires or in the

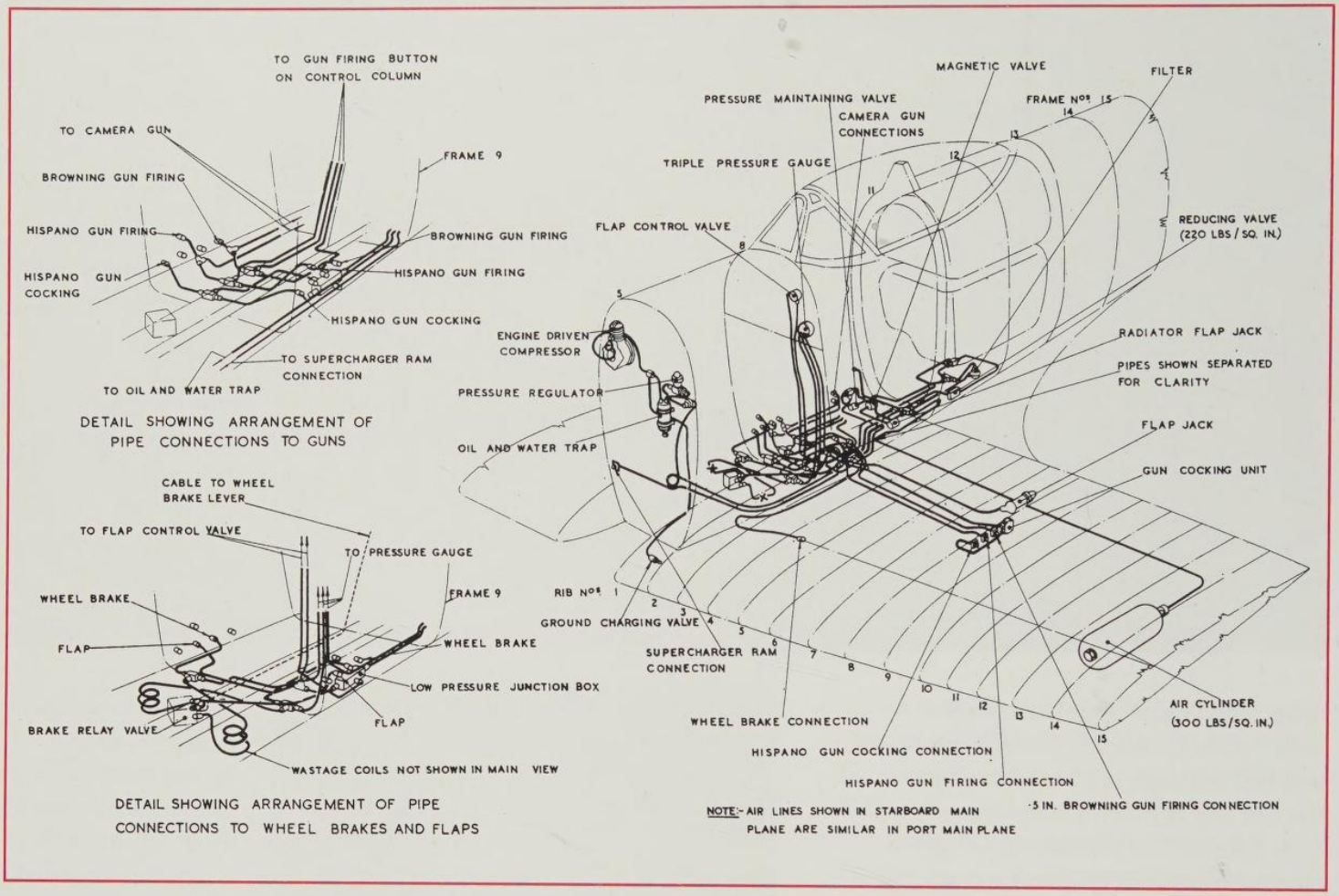




TOP: The crowded area immediately behind the engine, showing the hydraulic pump (silver) which supplies the system with pressure and is driven by spur gears from the camshaft-driven bevel gears. The air compressor (black) is adjacent to it. *(P. Blackah/Crown Copyright)*

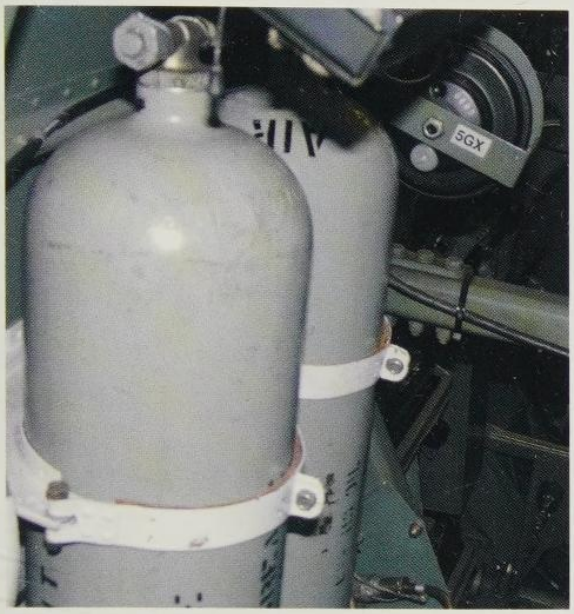
MIDDLE: The hydraulic reservoir location on the top forward face of fuselage Frame 5. *(P. Blackah/Crown Copyright)*

BOTTOM: The modern undercarriage emergency air bottle, aft of fuselage Frame 11. This is used to lower the undercarriage and lock it down in the event of an hydraulic failure. *(P. Blackah/Crown Copyright)*



ABOVE: **A diagram from AP1565 showing the layout of the pneumatic system components on a 'low-back' Spitfire.** *(Crown Copyright)*

RIGHT: **On 'low-back' Spitfires, such as the Mark XIV, the pneumatic system is fed with compressed air by cylinders located in the redundant wing outer gun bays. This view shows the securing strap with the bottle removed.** *(P. Blackah/Crown Copyright)*



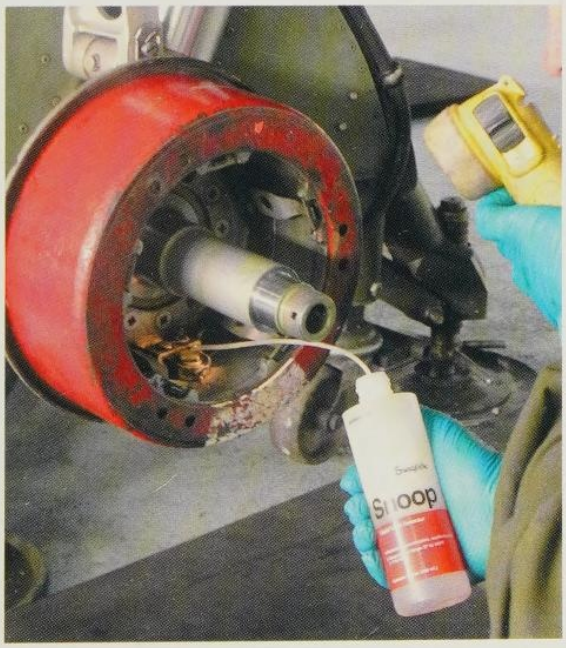
TOP LEFT: On 'high-back' Spitfires, such as the Mark IX, the pneumatic system is fed with compressed air by two cylinders fitted on the port side of the fuselage behind Frame 11. *(P. Blackah/ Crown Copyright)*

TOP RIGHT: The oil and water trap for the pneumatic system, located on the front of fuselage Frame 5, behind the engine. *(P. Blackah/Crown Copyright)*

outer gun bays on the port and starboard wings on 'low-back' variants. The cylinders are kept charged by an engine-driven compressor, mounted on the rear of the engine starboard cylinder block. The supply from the compressor passes through a regulator valve that limits the system pressure to 300psi, and then to an oil and water trap where any oil/water mist is collected. (The trap is drained on BBMF aircraft every 28 flying hours.) The supply then passes through a filter to a reducing valve, which lowers the pressure to 140psi before routing it to the relevant systems. The main system pressure is indicated on a triple pressure gauge at the left-hand lower side of the instrument panel.

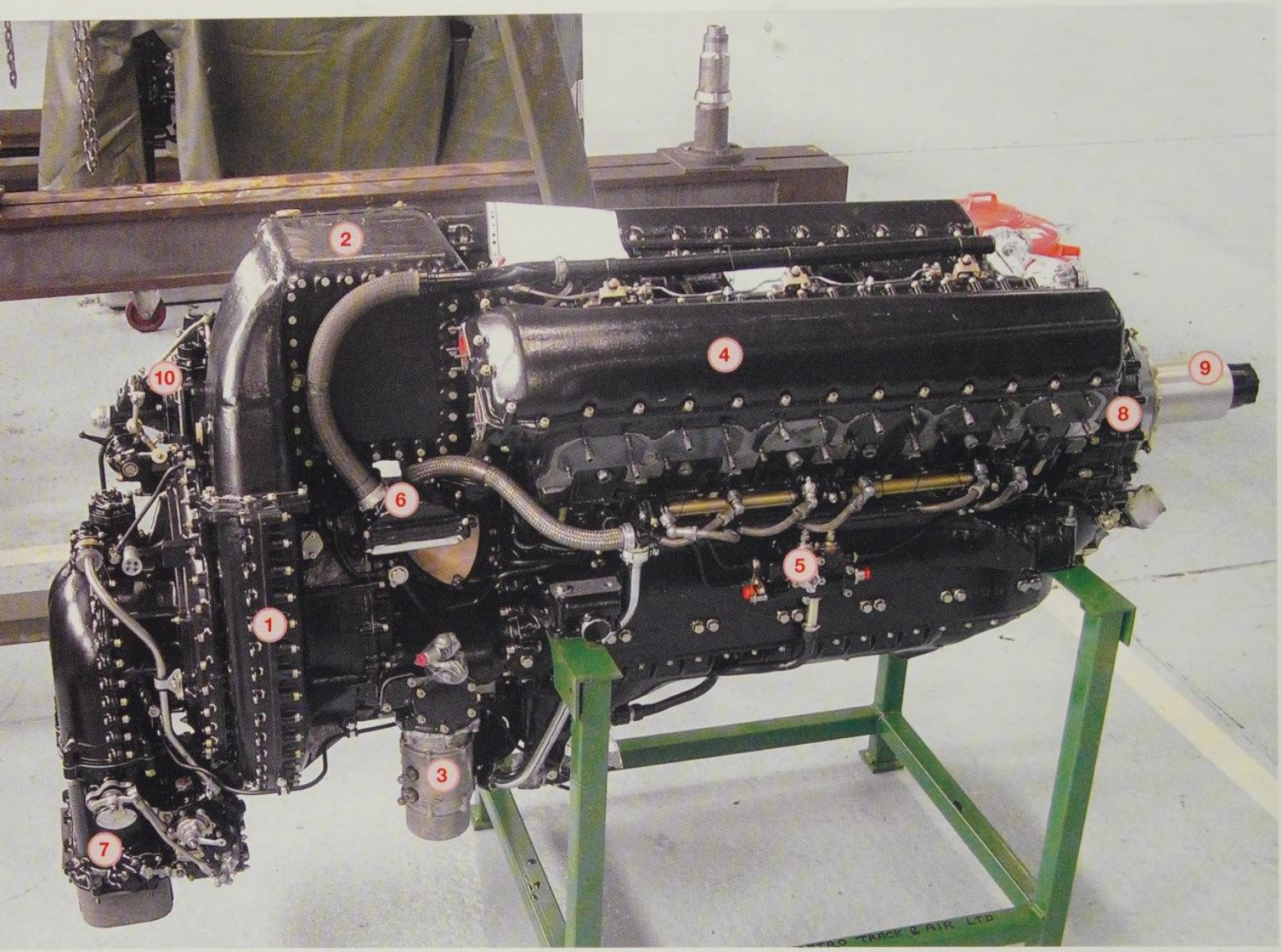
Brakes

The brake units are fitted to the undercarriage main axles, and are operated by a bicycle-like brake lever on the control column spade grip. The lever is connected to a brake control valve via a Bowden cable. Operating the lever supplies compressed air to the drum brake air bags, and when fully applied the braking pressure is 90psi per side. Movement of the rudder bar whilst the brakes are applied provides differential braking to allow the aircraft to be steered on the ground. The rudder bar is connected to a brake control valve via an adjuster rod. Braking pressures are indicated on a triple gauge positioned at the left-hand lower side of the instrument panel.



BOTTOM LEFT: A 12in wheel brake unit, showing the brake shoes. The shoes are operated by a rubber bag which, when inflated by pneumatic pressure, pushes the brake shoes out against the drum. *(P. Blackah/Crown Copyright)*

BOTTOM RIGHT: If there is a leak in the pneumatic system, it cannot be seen. To detect leaks, a Snoop liquid – a mild, non-corrosive detergent – is sprayed into the suspected area, in this case a wheel brake. If the liquid comes into contact with the stream of leaking air, it forms bubbles to show where the problem lies. *(P. Blackah/ Crown Copyright)*



ABOVE: A Packhard-built Merlin 266 engine ready for fitting to an airframe. *(P. Blackah/ Crown Copyright)*

1 Two-stage two-speed supercharger
2 Intercooler
3 Starter Motor
4 Cam cover
5 Oil control valve
6 Wiring harness to Magnetos
7 Carburettor
8 Reduction gear
9 Prop shaft
10 Automatic boost control

Flaps

A pneumatic jack in each wing operates the two-position flaps, which are connected. The flap operating lever, painted white and marked 'Up' and 'Down', is located at the top left of the instrument panel. When 'Down' is selected, compressed air enters the jacks to push the flaps down. When 'Up' is selected, the air is released to atmosphere and the flaps are raised by air pressure assisted by a spring.

The Merlin 61/66 engine

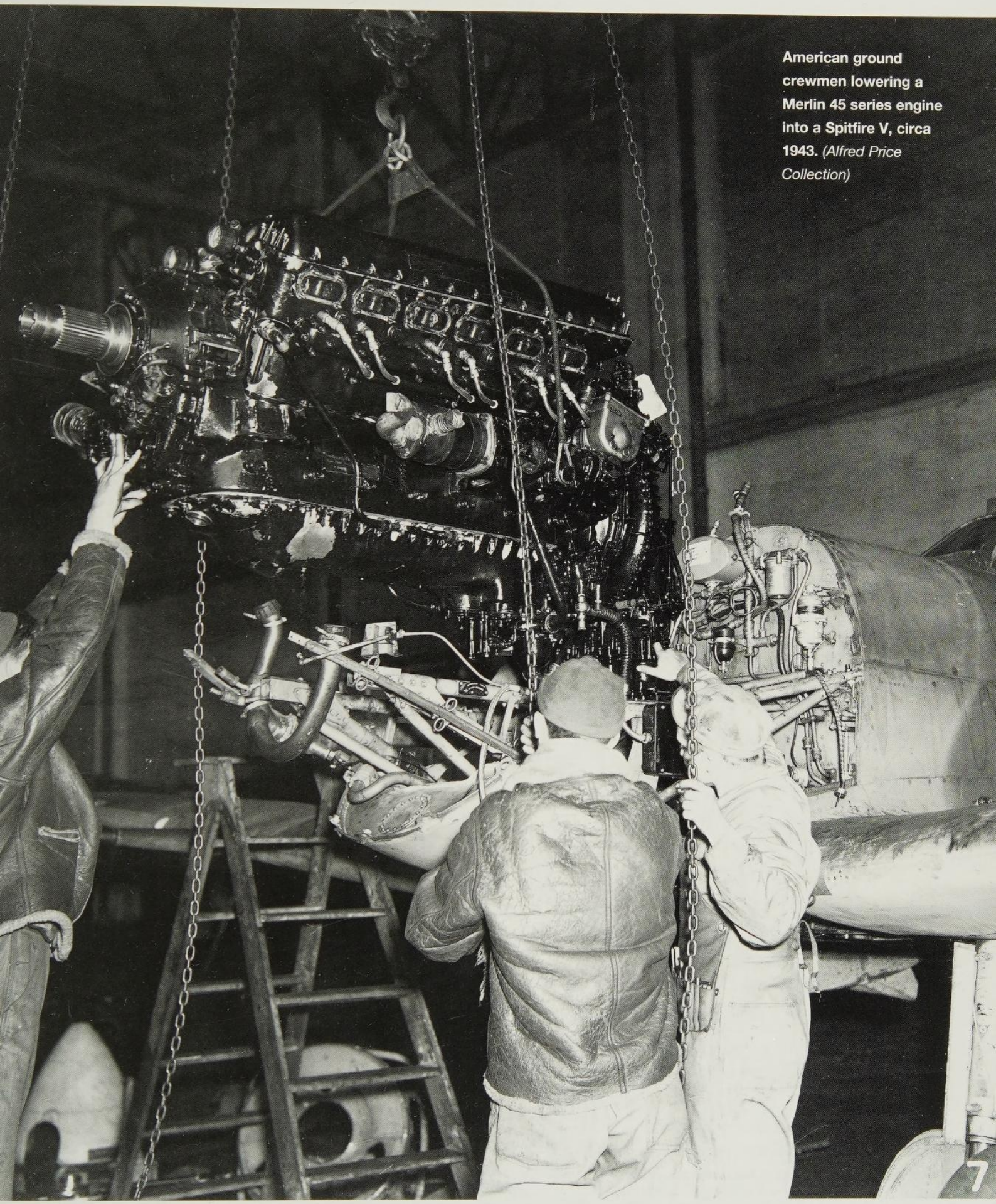
The Merlin 61/66 fitted to the Spitfire IX is a 27-litre, 12-cylinder, 60° Vee-12, liquid-cooled engine. It has a compression ratio of 6:1 and its dry weight is 1,640lb.

The two-piece cylinder block is cast from aluminium alloy. There are six cylinder liners in each block, manufactured from high carbon steel. Each piston has three compression and two oil scraper rings. The connecting rods are nickel steel forgings, machined to H-sections. The one-piece six-throw crankshaft is machine forged from chrome-molybdenum steel. The crankcase is cast from aluminium alloy. Two inlet and two exhaust valves are fitted to each cylinder head and each exhaust valve has a sodium-cooled stem.

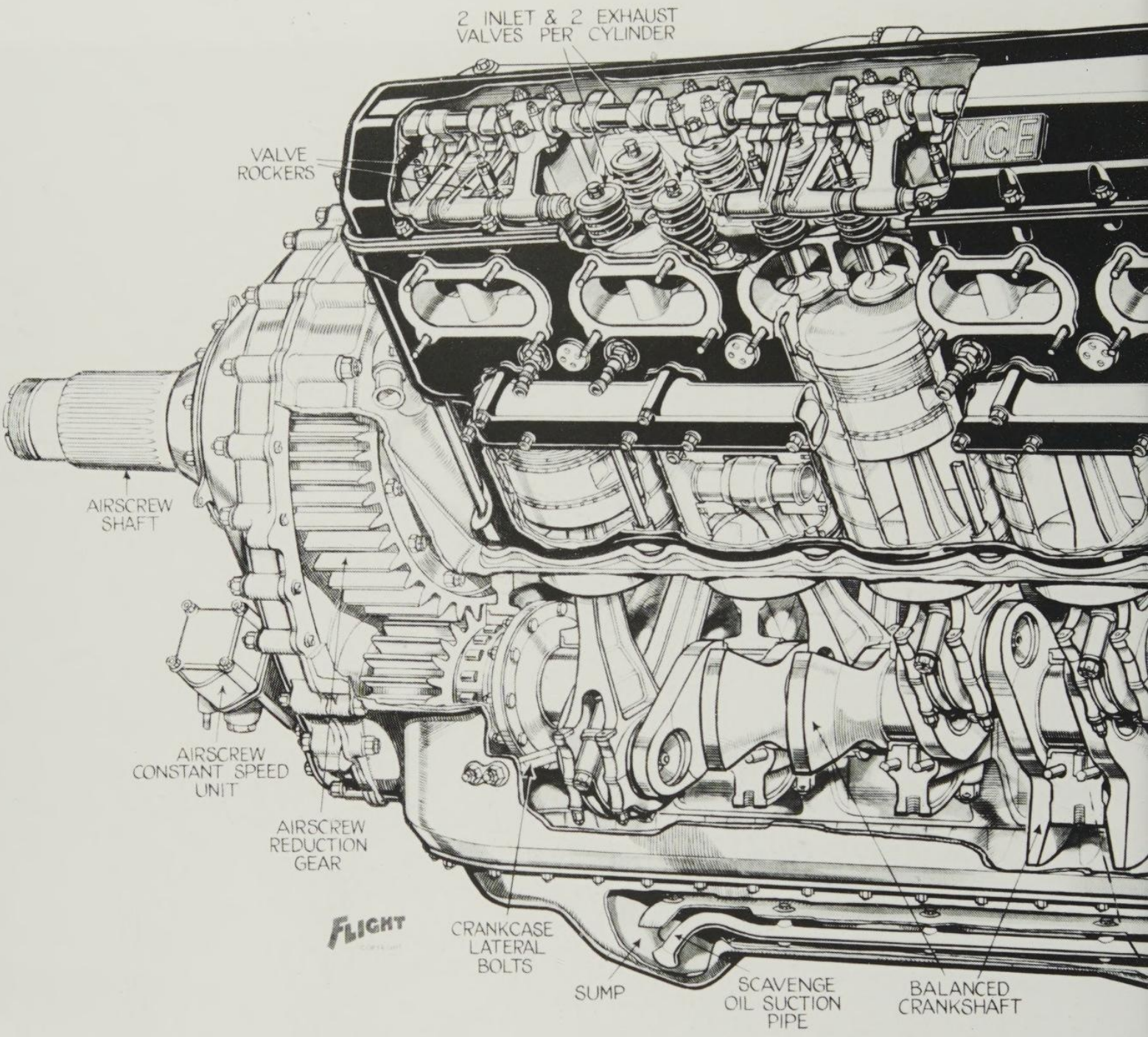
The engine comprises the following components.

Cylinders

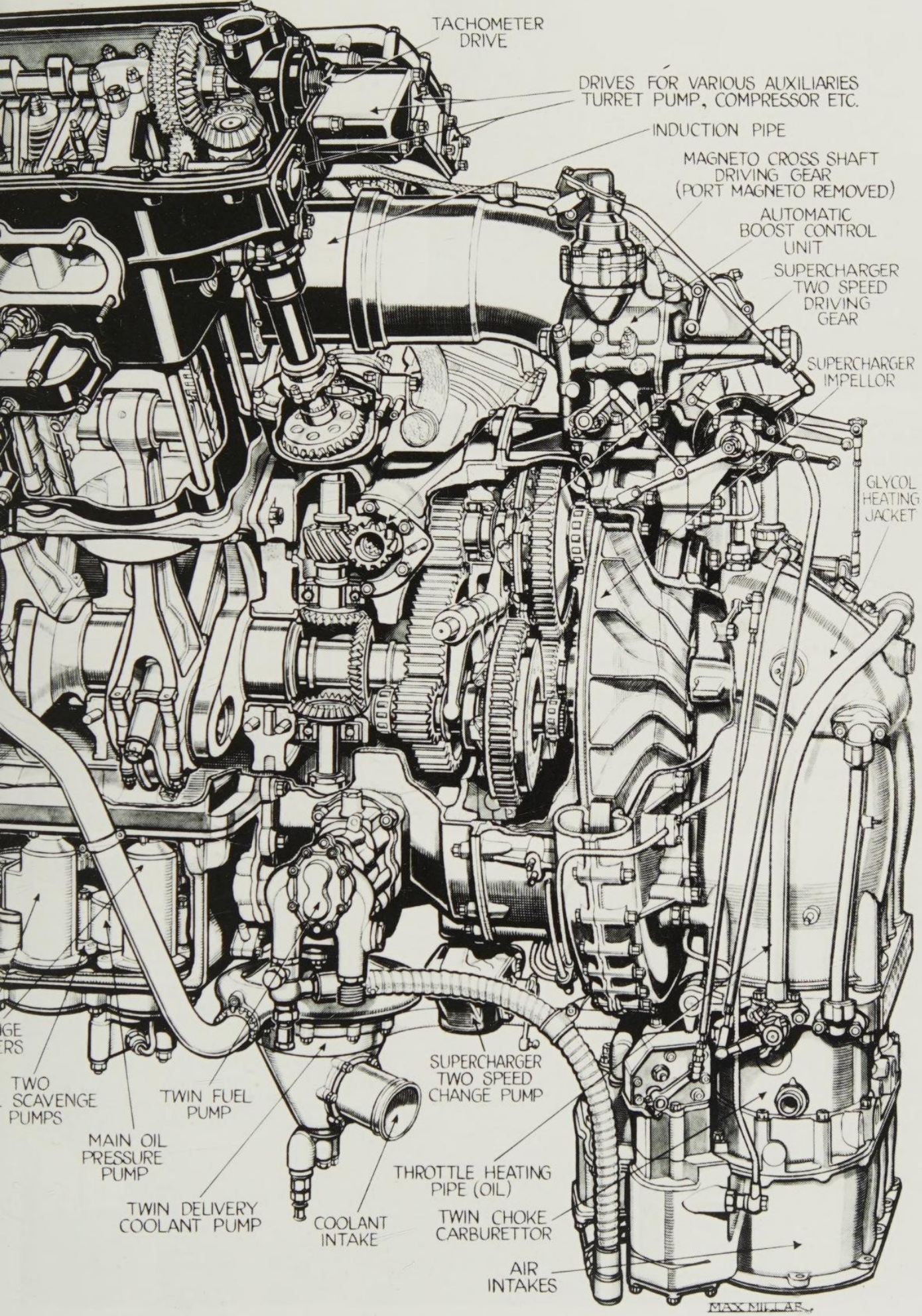
The two cylinder assemblies, namely the right- and left-hand blocks, are known as the A and B blocks respectively. Each comprises six cylinders, the upper camshaft drive unit and the camshaft and rocker mechanism, which operates the valves incorporated in the cylinders. Each block consists of a separate alloy skirt and head, which when bolted

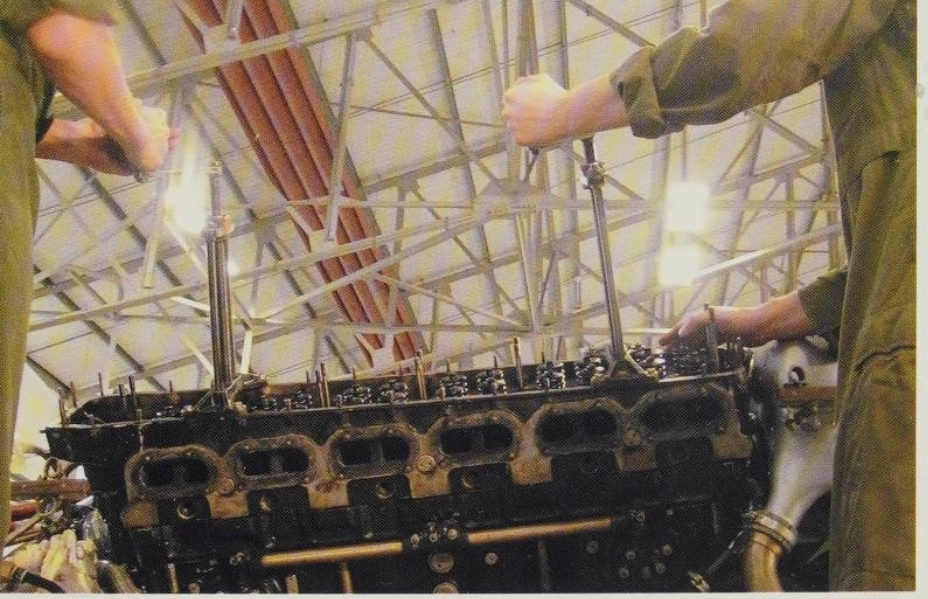


American ground crewmen lowering a Merlin 45 series engine into a Spitfire V, circa 1943. *(Alfred Price Collection)*



A superb cutaway illustration of the Merlin 45 engine. The Merlin 45 and its derivatives originally powered Spitfire Marks V and VI and Seafire Marks II and III. *(Flight International)*

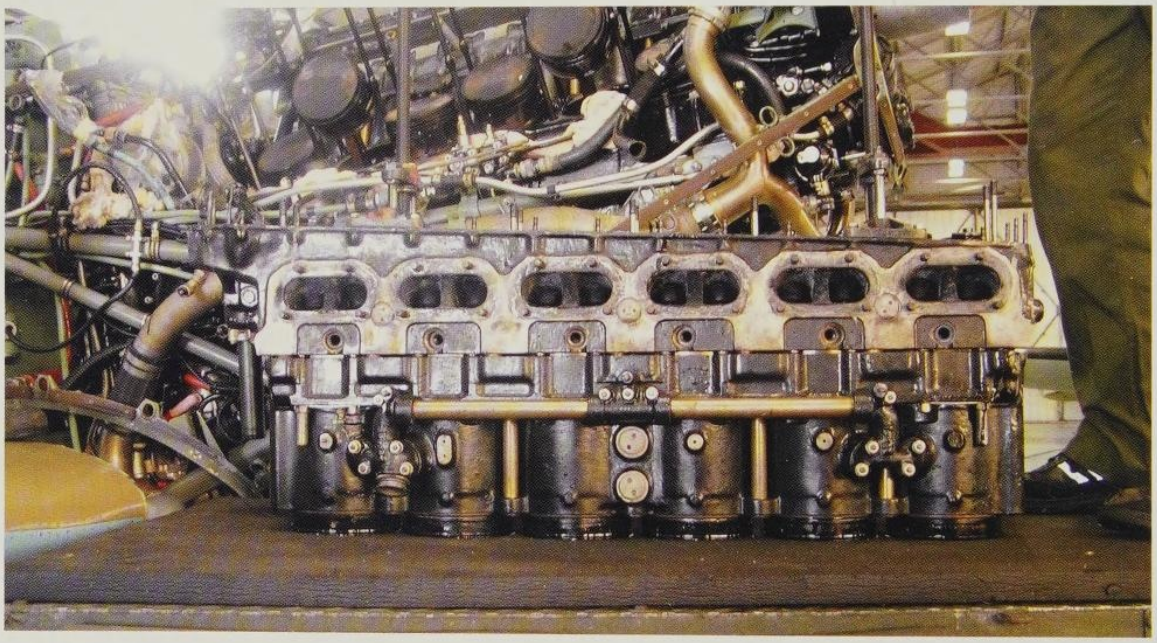

TACHOMETER DRIVE
DRIVES FOR VARIOUS AUXILIARIES TURRET PUMP, COMPRESSOR ETC.
INDUCTION PIPE
MAGNETO CROSS SHAFT DRIVING GEAR (PORT MAGNETO REMOVED)
AUTOMATIC BOOST CONTROL UNIT
SUPERCHARGER TWO SPEED DRIVING GEAR
SUPERCHARGER IMPELLOR
GLYCOL HEATING JACKET
TWO SCAVENGE PUMPS
TWIN FUEL PUMP
MAIN OIL PRESSURE PUMP
SUPERCHARGER TWO SPEED CHANGE PUMP
THROTTLE HEATING PIPE (OIL)
TWIN DELIVERY COOLANT PUMP
COOLANT INTAKE
TWIN CHOKE CARBURETTOR
AIR INTAKES
MAX MILLAR



together form the cylinder block proper, and six detachable wet steel liners. In addition to providing part of the coolant jacket, the head also forms the roofs of the six combustion chambers.

Cylinder liners

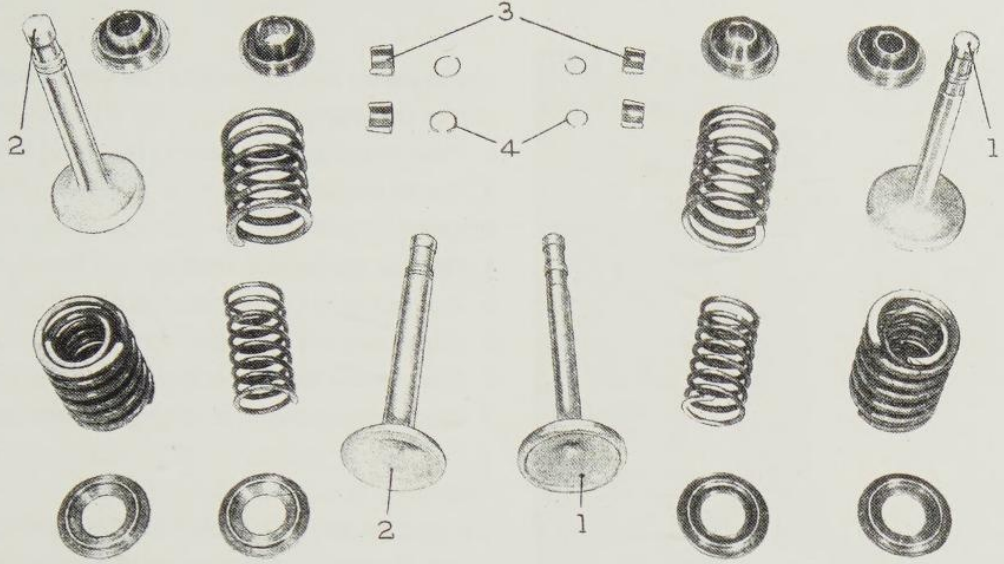
Each cylinder liner is shouldered and spigotted at the upper end to enter its respective recess in the bottom of the cylinder head. The cylinder liner is also provided with a sealing ring at its lower end to form a joint with the crankcase, to which it is drawn by the cylinder holding-down studs.



ABOVE: Cylinder block removal tools fitted to the Merlin in the airframe of Mark VB AB910. The handles on the two tools are being turned to begin lifting the block from the crankcase. *(P. Blackah/Crown Copyright)*

MIDDLE: The starboard cylinder block from AB910's Merlin on the bench after removal. The exhaust ports can be seen at the top of the block, with the holes for the exhaust-side spark plugs below. *(P. Blackah/Crown Copyright)*

BOTTOM: With the block removed, the exposed pistons can be seen protruding from the crankcase in the airframe. *(P. Blackah/Crown Copyright)*



Merlin engine valve components. *(Crown Copyright)*

1 Inlet valves
2 Exhaust valves
3 Valve collets
4 Valve collet retaining circlips

Cylinder block covers

The covers are secured to their respective cylinder blocks by studs and nuts, with a gasket between the two contacting faces. The main difference between the A and B covers is that the latter incorporates an engine speed indicator drive whilst the former is plain.

Valves

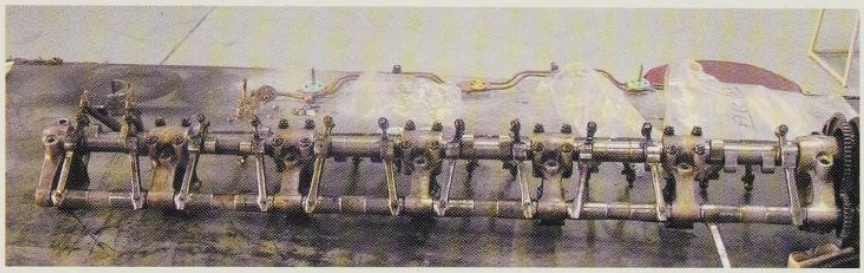
There are two inlet and two exhaust valves per cylinder. Both valves are of the trumpet type and have stellite-ended stems. The valve guides are cast iron for the inlet and phosphor-bronze for the exhaust. The valves are not interchangeable. Each valve guide is pressed into its respective bore in the cylinder block until a conical collar near its top end is seated on, and is flush with, the roof of the cylinder block.

Camshaft

A single central camshaft for each cylinder block is mounted in pedestal brackets and operates both inlet and exhaust valves through rockers fitted with adjustable tappets. The camshafts, which are similar for both blocks, are driven from the wheel case by inclined shafts ending in bevel pinions that mesh with bevel wheels at the end of each camshaft.

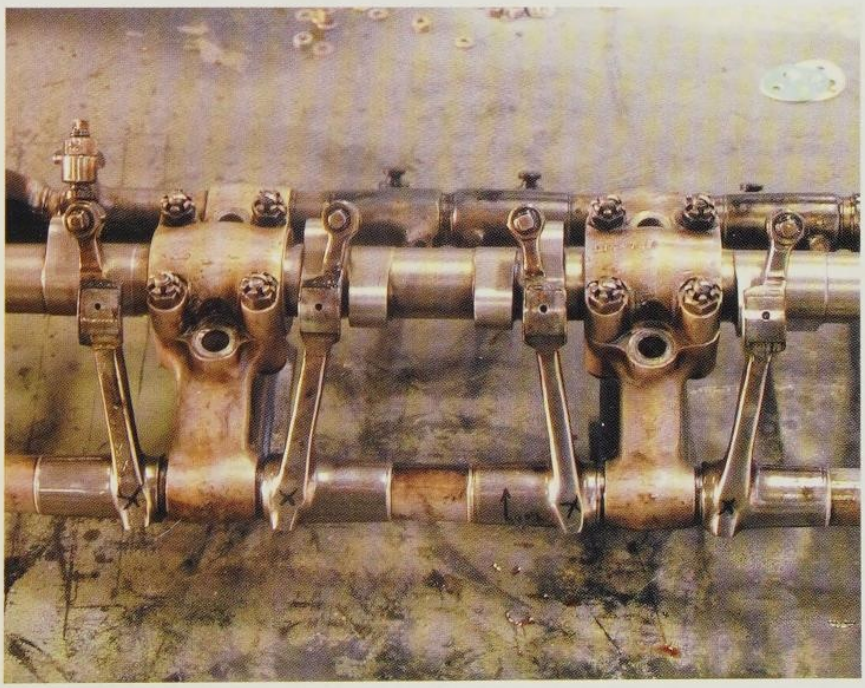
Camshaft auxiliary drives

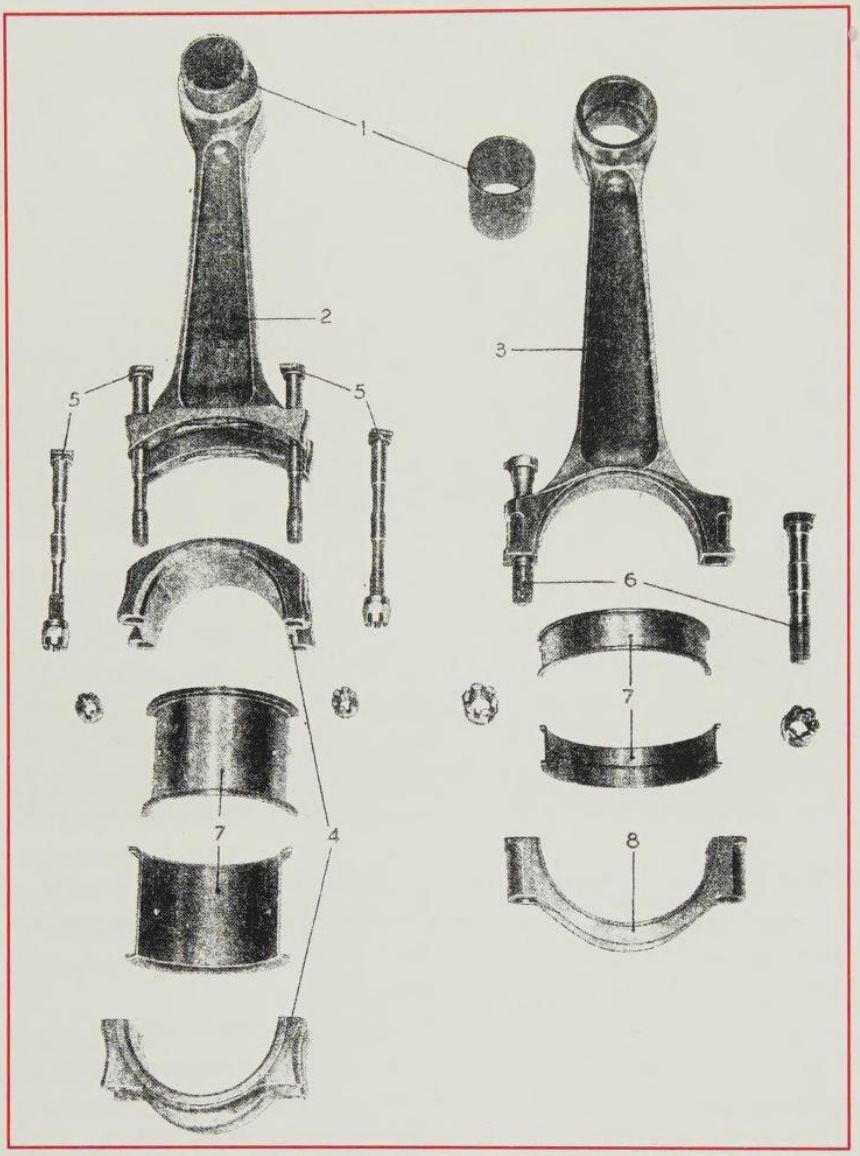
The air compressor and hydraulic pump are mounted on the rear ends of the A-bank cylinder head. Both are driven from the spur gear wheels attached to the camshaft-driven bevel wheels.



ABOVE: The camshaft and rocker assembly from AB910's Merlin. A single camshaft on each cylinder bank operates both the inlet and exhaust valves on the bank. *(P. Blackah/Crown Copyright)*

BELOW: In this close-up view, the rockers have been rotated to allow inspection of the rocker-to-camshaft contact faces. When fitted to the engine, the contact faces of the rockers (the faces with oil holes visible) fit under the camshaft. The tappet adjusters can be seen on the ends of the rockers. *(P. Blackah/Crown Copyright)*





Merlin piston and connecting rod components. *(Crown Copyright)*

1 Floating gudgeon pin bush
2 Forked connecting rod
3 Plain connecting rod
4 Split big-end bearing housing
5 Connecting rod bolts (forked rod)
6 Connecting rod bolts (plain rod)
7 Lead-bronze lined big-end bearing shells
8 Connecting rod big-end bearing cap (plain rod)

Pistons

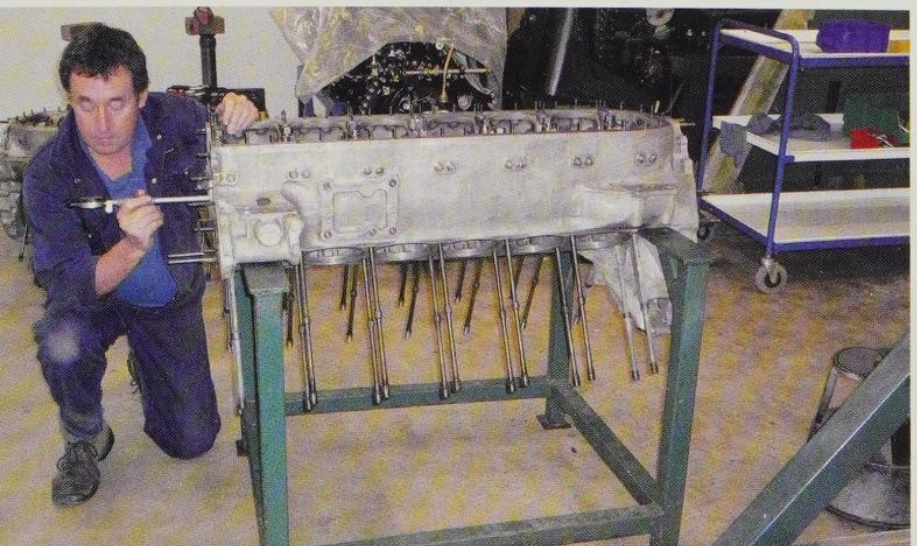
The pistons are attached to the connecting rods by fully floating gudgeon pins. The connecting rods are of the forked and plain type, the forked rod being fitted to the B-side of the engine. The pistons are machined from light alloy forgings and are fitted with three compression rings above and one grooved scraper ring below the gudgeon pin. The gudgeon pins are made from hollow steel and are retained in the piston by spring wire circlips. A pair of oil holes is drilled obliquely and upwards towards the centre to meet in the metal above each gudgeon pin bore to assist in cooling the piston.

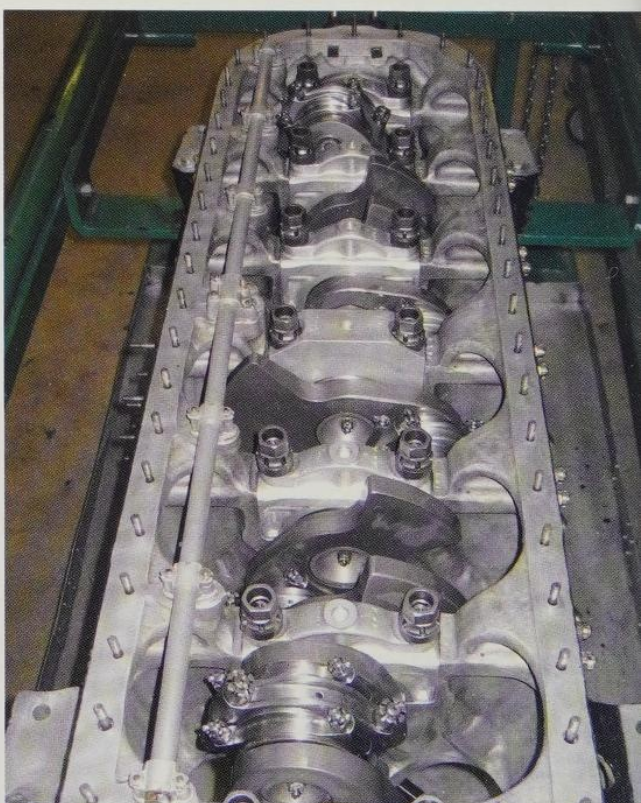
Crankcase

The crankcase, which consists of two halves bolted together, incorporates the rear half of the reduction gear housing at its front end, and has a facing and spigot at the rear end to which the wheel case is attached.

BELOW: Neil Smart painstakingly inspecting a Merlin crankcase at Retro Track and Air. *(Alfred Price Collection)*

RIGHT: A view of a Merlin crankshaft in situ in the crankcase. In the foreground, the forked/plain connecting rod arrangement can be clearly seen, with the big-end bearing cap of the plain connecting rod fitted in the centre of the two bearing caps of the forked rod. *(Crown Copyright)*





Crankshaft
The crankshaft is of the normal six-throw balanced type and provides drives for the reduction gear and wheel-case components through a built-up internally toothed flange at its front end and through internal splines at its rear end respectively.

Reduction gear
The reduction gear is of a single-spur layshaft type and is housed partly in a casing bolted to the front end of the crankcase and partly in the crankcase itself. The casing is located on the crankcase by means of a spigot concentric with the propeller shaft. The driving pinion is concentric with, and is driven by, a short coupling shaft from the crankshaft. All these shafts run in roller bearings, the propeller shaft having, in addition, a thrustable ball-bearing, enabling the engine to be used with a tractor (pulling) or a pusher propeller. A dual-drive unit is fitted to the reduction gear cover for the purpose of driving the propeller constant speed unit (CSU) and vacuum pump unit, which are both bolted to it. The vacuum pump is used for the operation of certain cockpit instruments.

Wheel case assembly
The wheel case is bolted to the rear end of the crankcase and carries the magnetos, coolant pump, generator drive, electric turning gear and the fuel pump unit. It houses the spring-drive unit and certain shafts through which the magnetos, camshafts, electric generator, fuel, oil and coolant pumps are driven.

Coolant pump
The coolant pump is of the bottom-fed centrifugal type and serves each cylinder block from a separate outlet.

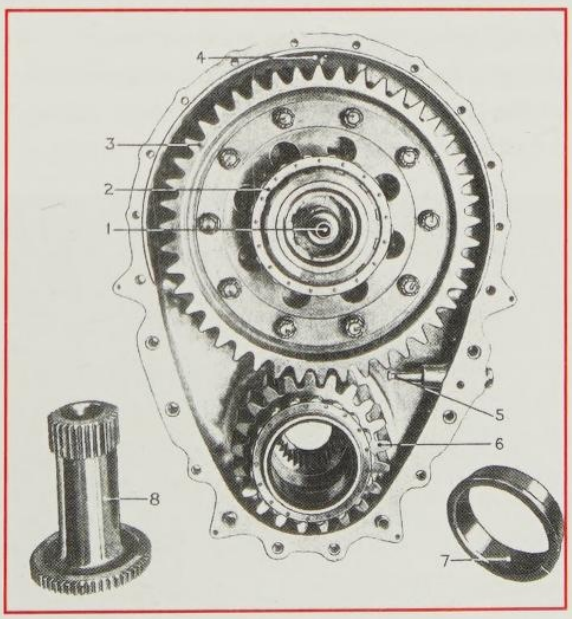
Intercooler pump
This is mounted on the rear of the generator-drive housing, attached to the port side of the crankcase, and circulates coolant from the header tank to the radiator.

Fuel pump
The fuel pump unit, mounted on the facing on the port side of the wheel case, consists of two separate pumps operating in parallel. Each pump is capable of operating independently of the other and each is of sufficient capacity to supply more than the maximum amount of fuel required.

ABOVE: A Merlin 266 crankshaft removed for inspection. A pair of pistons connects to each crankshaft throw – one piston on each cylinder bank.
(Crown Copyright)

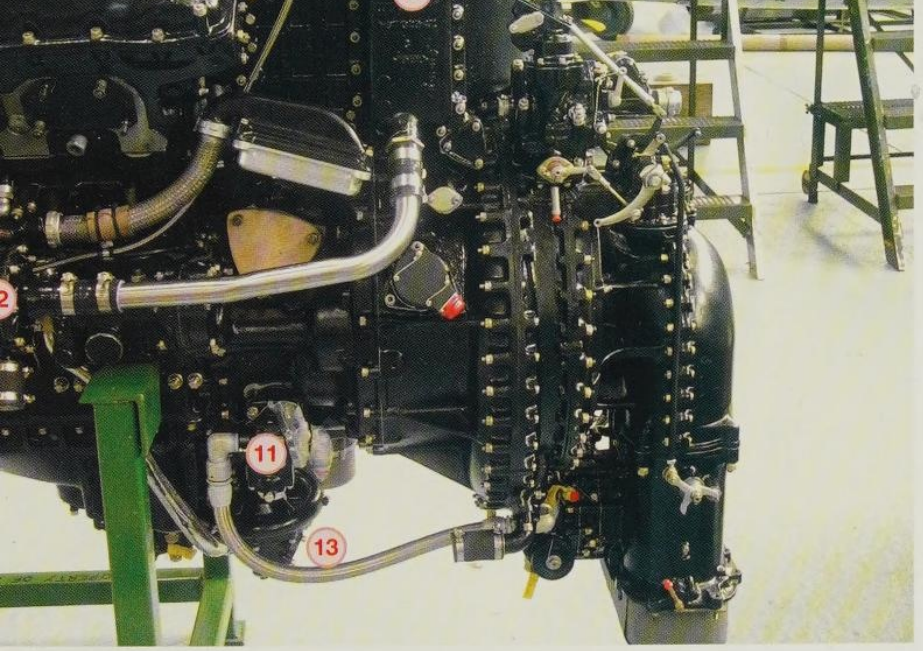
Electrical generator and intercooler pump drive
The electrical generator and intercooler pump drive housing, on which the generator and the intercooler pump are mounted, is attached to a facing on the port side of the crankcase.

Supercharger
The two-speed, two-stage, liquid-cooled supercharger is of the tandem two-rotor centrifugal type and is driven from the rear end of the crankshaft through a two-speed



LEFT: A rear view of a Merlin propeller reduction gear assembly.
(Crown Copyright)

1 Oil feed tube for propeller pitch control
2 Propeller shaft rear roller bearing race
3 Propeller shaft gear
4 Connection for slinging eye
5 Oil jet
6 Driving pinion
7 Propeller hub centring cone
8 Engine coupling shaft



ABOVE: Merlin 266 intercooler and supercharger assemblies. *(P. Blackah/Crown Copyright)*
11 Fuel pump
12 Intercooler coolant pump
13 Coolant pump
14 Intercooler coolant tank

gear. The drive is effected through the spring drive and a speed-increasing gear-train, which incorporates the two-speed gear mechanism and comprises three lay driving spindles, each incorporating a centrifugally loaded clutch.

The intercooler assembly
An intercooler is fitted to the engine for the purpose of reducing the very high delivery mixture temperature generated by the two-stage supercharger. A separate cooling system is incorporated, the coolant being circulated by a centrifugal-type pump mounted on the generator drive housing on the port side of the engine.

Carburetion
The SU twin-choke updraught-type Merlin carburettor fitted to this engine is, with the exception of the separate boost control unit, entirely self-contained. It is arranged to be fully automatic in its functioning, so danger of engine damage resulting from incorrect setting is much reduced.

The SU-type Merlin A.V.T.44/199 or 215 carburettor embodies two complete carburettors in one complete unit. The flow of fuel through the left-hand carburettor main jet is directly controlled by the induction pressure-operated mixture control, whilst the right-hand jet is directly controlled by the atmospherically-operated mixture control. Both these mixture controls are automatically controlled through linkwork by separate aneroid capsules on each side of the carburettor. The upper half of the carburettor casting is mounted on studs on the lower face of the supercharger intake elbow. A large specially-shaped gasket provides a gas- and fuel-tight joint. Both the vertical intake passage and throttle barrels are coolant jacketed, these jackets being included in the coolant return from the B cylinder block to the inlet side of the coolant pump. A system of oil-heated throttle valves is included, to prevent freezing and to allow a portion of the scavenge oil to be directed through the hollow interior of the throttle valves before it is returned to the oil tank.

Ignition system
The ignition system comprises two magnetos attached to the wheel case, one on the left and one on the right. Attached to these are the high-tension wiring harnesses for the spark plugs. These are metal screened and serve a dual purpose. They act as a collector for the induced field around the high tension wires and return the resulting electrical current to earth. They also prevent radio interference. Each cylinder has two spark plugs – one magneto provides the spark for the inlet-side plugs and the other for the exhaust-side plugs. This ensures that if one magneto fails, the engine will still run on the other magneto.

RIGHT: A Merlin spark plug, giving an idea of its size. The HT lead connection screws onto the top of the plug. *(P. Blackah/Crown Copyright)*

FAR RIGHT: The twin earth electrodes can be clearly seen in this view of the end of a Merlin spark plug. *(P. Blackah/Crown Copyright)*

Engine lubrication system

There are four oil circuits in the lubrication system of the engine, namely:

1. The main pressure circuit
2. The low pressure circuit
3. The front sump scavenge circuit
4. The rear sump scavenge circuit

The main and lower circuits are served by a single pressure pump and suitable relief valves, while each scavenge circuit is served by a separate scavenge pump.

Fuel system

The carburettor has an automatic mixture control device and supplies the fuel/air mixture to the supercharger. The latter is of the two-speed, two-stage type, controlled by an automatic servo mechanism. An intercooler is positioned between the two stages of the supercharger, and the hot coolant is ducted to a radiator under the starboard wing and then back to the header tank.

The fuel is held in two tanks located behind main fuselage Frame 5, the fireproof bulkhead. The upper tank has a capacity of 48 gallons and, on the Mark IX, the lower tank 37 gallons, giving a combined total of 85 gallons, equating to roughly two hours' flying time. Both tanks are filled via a single screw-cap in the upper tank. During engine running the upper fuel tank drains into the lower tank, which feeds the engine.

The fuel on/off switch is located in the cockpit to the right of the compass. When selected, it operates a fuel cock in the lower fuel tank.

The lower tank has a self-sealing rubberised covering, which functioned as follows. When a bullet or shell splinter pierced the tank below the fuel level, fuel started to leak out. When the fuel came into contact with the rubberised covering, it set up a chemical reaction that caused the rubber to swell until it sealed off the hole.

The fuel system is designed to use 100 octane fuel. (Today the fuel used is 100 LL – 100 octane Low Lead; the engine does not require modification to accommodate the change in fuel.)

Merlin 66 engine specifications

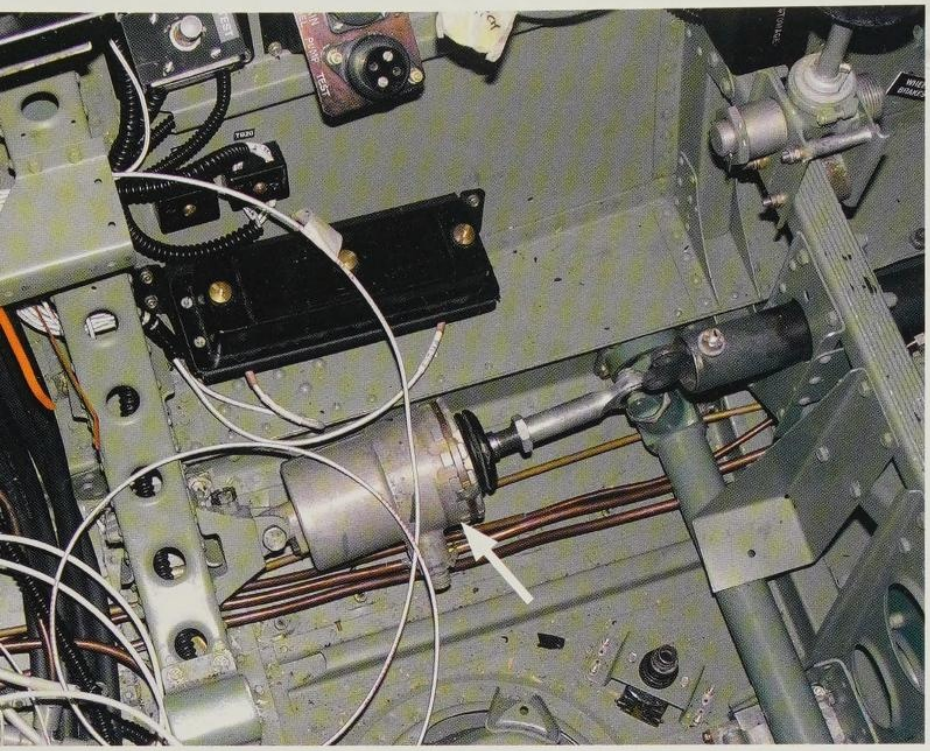
Type of engine	Supercharged, geared, pressure liquid-cooled V-engine, fitted with a two-stage, two-speed liquid-cooled supercharger with intercooler
Number of cylinders	12
Arrangement of cylinders	2 banks of 6 cylinders each with an inclined angle of 60°
Bore	5.4in (137.6mm)
Stroke	6in (152.4mm)
Swept volume	1,648cu in (27.0 litres)
Cylinder firing order	1A, 6B, 4A, 3B, 2A, 5B, 6A, 1B, 3A, 4B, 5A, 2B
Magnetos	2, port clockwise, starboard anticlockwise rotation
Starting system	electric turning gear

Cooling system

The liquid coolant is a mixture of 70 per cent distilled water and 30 per cent ethylene glycol, and the system has a capacity of 14½ gallons. The header tank is mounted over the reduction gear casing at the front of the engine. A pipe from each side of the header tank runs down the side of the engine, through a thermostat.

FAR LEFT: Fuel tanks from a Spitfire Mark XVI with modified lower tank for increased range. The top tank (48 gallon capacity) is on the left of the photograph and the bottom tank (47 gallon capacity) on the right. *(P. Blackah/Crown Copyright)*

LEFT: Mark IX fuselage, with covers removed to show the location of the upper fuel tank. *(P. Blackah/Crown Copyright)*

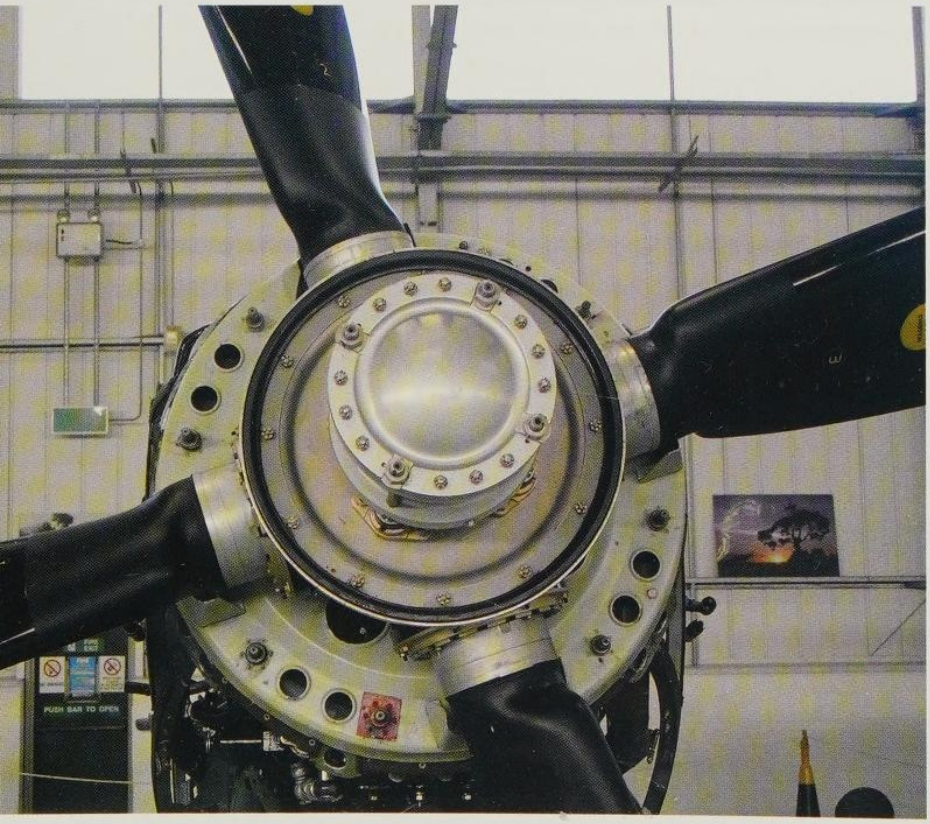


ABOVE: Coolant header tank location at the front of the engine – viewed from the port side. The filler cap can be seen in the side of the tank. *(P. Blackah/Crown Copyright)*

LEFT: Thermostatically controlled radiator flap operating jack location (arrowed) on the cockpit floor. The jack rotates the arm, which can be seen running across the floor behind it, to operate both radiator flaps. *(P. Blackah/Crown Copyright)*

BELOW: A view of the propeller pitch control unit, seen with the propeller spinner removed. *(P. Blackah/Crown Copyright)*

The pipes then pass through the fuselage spar at Frame 5 to the radiators on the port and starboard wings. The outlet from each radiator runs forward through the spar at Frame 5 to a coolant pump underneath the engine. A bypass pipe is connected between each thermostat and the coolant pump to ensure that coolant only passes through the radiators when operating temperature is reached.



Oil system

Lubrication is by means of a dry-sump system. The oil tank, with a capacity of 7½ gallons, is enclosed within the lower engine cowling panel. The supply is taken from the rear of the tank through to an oil filter, from where it passes to the engine. As the hot oil emerges from the rear of the engine it is piped to the oil-cooler radiator under the port wing.

Intercooler

The intercooler system uses the same type of coolant as the main engine cooling system. On the Spitfire Mk IX the intercooler header tank is located on main fuselage Frame 5, and has a capacity of 5 pints of coolant. Coolant is piped to an auxiliary coolant pump on the port side of the engine, and then from the pump to a radiator under the starboard wing. The coolant is directed to the bottom of the supercharger casing, where it flows up into the intercooler at the back of the engine before returning to the header tank.

Propeller

The propeller is a Dowty Rotol unit with four blades made from laminated spruce, diameter

10ft 9in. The propeller pitch is controlled by a constant speed unit.

Electrical system

Most original Spitfire and Seafire variants used a 12v electrical system that included a generator, a voltage regulator and a battery. Most Spitfires flying today have had their electrical systems uprated to 28v, allowing the engine to be started on the internal batteries.

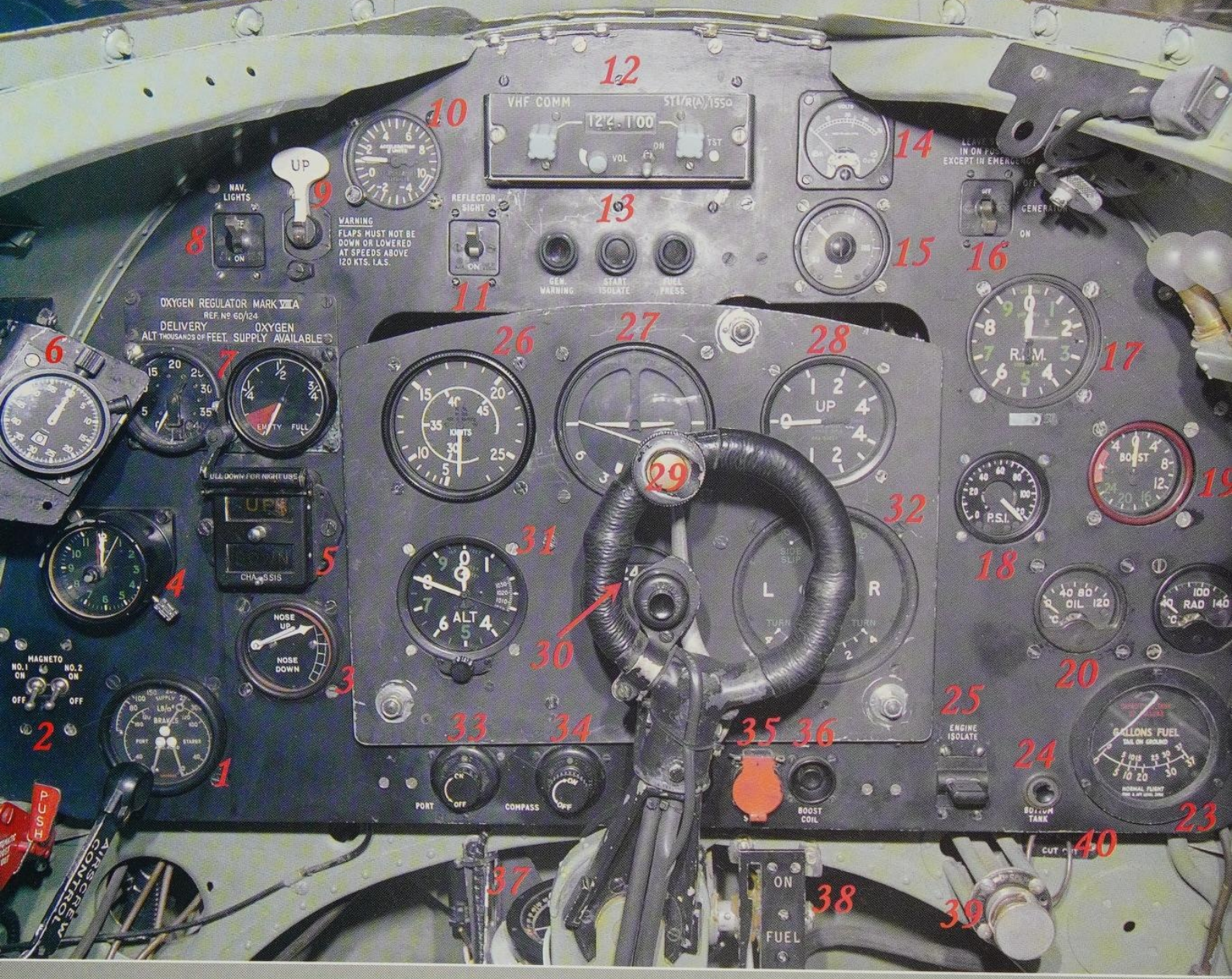
The electrical system runs up to 22 fused circuits, including:

- **The navigation lights** – there are three lights, one red (port wing tip), one green (starboard wing tip) and one white (rudder).
- **Downward identification light** – located in the cockpit lower skin, under the pilot's seat.
- **Cockpit lighting** – two lights are fitted, one on either side of the cockpit, set in flexible mountings to allow adjustment, and shielded to prevent glare.
- **Undercarriage position indicator** – mounted on the instrument panel, illuminating a red light for 'Up' and a green light for 'Down and locked'.
- **Radiator flaps** – operated by a switch mounted on the port side of the cockpit.
- **Supercharger** – switching to change over from low supercharger gear to high supercharger gear and back again (no longer used, as the switch was operated at approx 20,000ft, and Spitfires no longer fly at this altitude).
- **Fuel pump** – located in the lower fuel tank, controlled by a switch on a panel on the port side of the cockpit.
- **Pressure head heater** – the air speed indicator (ASI) is fed by a pressure head (pitot tube) on the port wing. A heating element can be switched on to prevent the pressure head icing over and giving false readings. The switch is mounted on the port side of the cockpit.
- **Fuel gauge** – mounted on the starboard side of the instrument panel, this shows only the fuel level in the lower tank. The gauge only indicates when a pushbutton, inboard of the gauge, is pressed.
- **Fuel pressure indicator** – illuminates a red warning light on the instrument panel if the fuel pressure falls below a safe working level.
- **Radio** – mounted on top of the instrument panel on BBMF aircraft, but may vary according to owner's preference. Original aircraft had the TR9, the TR1133 or the TR1143 radio. Surviving airworthy Spitfires carry modern solid-state radios.
- **IFF (identification friend or foe) equipment** – original aircraft carried the R3002 IFF. A modern transponder is required for identification purposes when flying in controlled airspace.
- **Engine starting button** – mounted on the instrument panel. When this button is pressed, a starter relay coil is energised which operates the starter motor. The booster coil button, immediately to its left, is pressed at the same time to boost the voltage from the magnetos.

ABOVE: The propeller from Mark XVI RW386 on a hoist ready to be fitted in the Aircraft Restoration Company (ARCo) hangar at Duxford. *(Alfred Price Collection)*

Not all of these systems are in use on every Spitfire flying today, and much is down to the owner's preference. Some owners like to have all the original features operative, whilst others will only have what is currently required to fly the aircraft safely.

The fuse boxes were originally positioned on the port side of the cockpit, by the access door, and the battery was positioned to the rear of the fuselage near the rear access door.

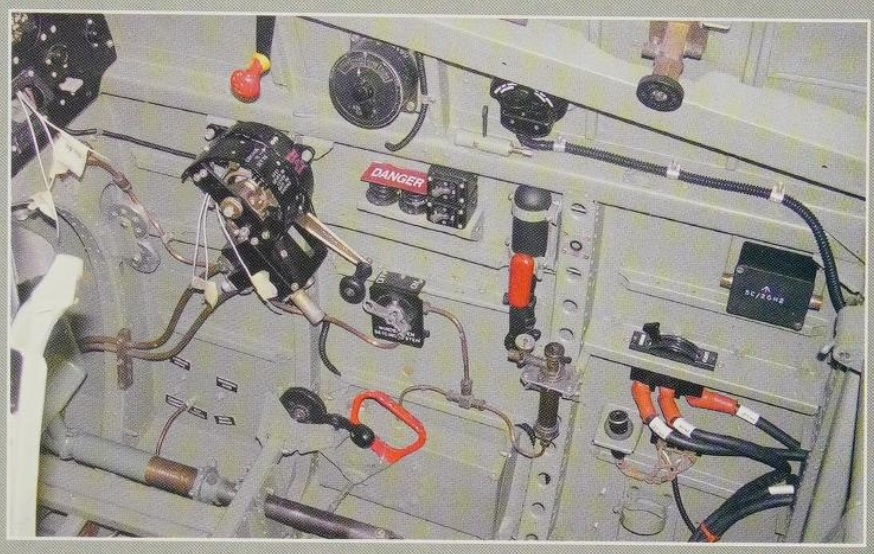


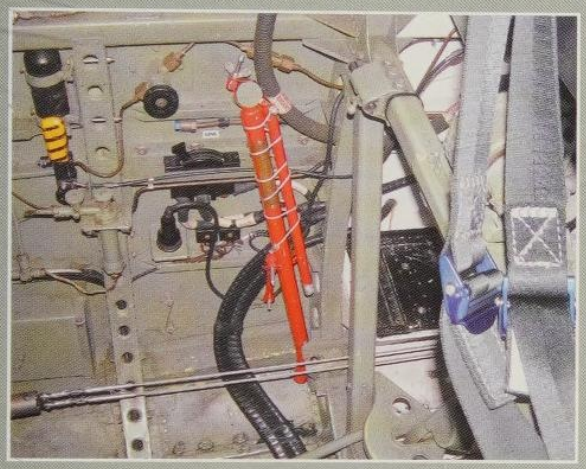
The instrument panel of Spitfire II P7350, belonging to the Battle of Britain Memorial Flight. *(RAF Coningsby Photo Section/Crown Copyright)*

The Instrument Panel

1 Triple brake gauge (system pressure, port/starboard brake indication)
2 Magneto switches
3 Elevator trim gauge
4 Aircraft clock
5 Undercarriage indicator (up and down)
6 Display stopwatch
7 Oxygen regulator (not used)
8 Navigation lights switch
9 Flap selector lever
10 Accelerometer (basic 'G' meter)
11 Gunsight button (not used)
12 Control panel for Marconi AD120 (modern radio)
13 Warning lights, generator, start isolate and fuel pressure
14 Voltmeter
15 Ammeter
16 Generator failure switch
17 RPM gauge
18 Oil pressure gauge
19 Boost gauge
20 Oil temperature gauge
21 Radiator temperature gauge
22 Cartridge starter breech control (not used)
23 Fuel gauge
24 Pushbutton to read contents of bottom fuel tank
25 Engine isolate switch
26 Air speed indicator
27 Artificial horizon
28 Rate of climb and descent indicator
29 Spade grip, featuring press to transmit, gunbuttons and brake lever
30 Directional gyro
31 Altimeter
32 Turn and slip indicator
33 Cockpit lighting dimmer switch
34 Compass lighting dimmer switch
35 Engine start button
36 Boost coil button
37 Compass
38 Fuel selector lever
39 Fuel primer pump
40 Engine stop ring pull handle

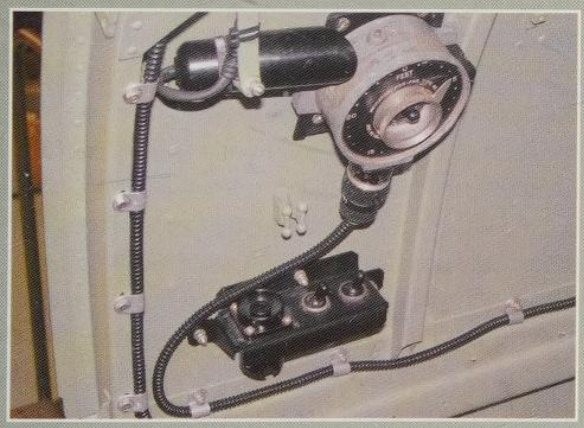
ABOVE: The spade grip in the cockpit of Mark IX MK356, complete with gun firing button (arrowed). *(P. Blackah/Crown Copyright)*





ABOVE: Starboard side of cockpit of Mark XVI TE311, showing the canopy winding handle (red/yellow), gyro gunsight selector, undercarriage selector with cover off, undercarriage emergency air bottle with red handle, below which is the windscreen de-icing pump, selector and tank and in front of that is the drop-tank jettison lever (red D handle). *(P. Blackah/Crown Copyright)*

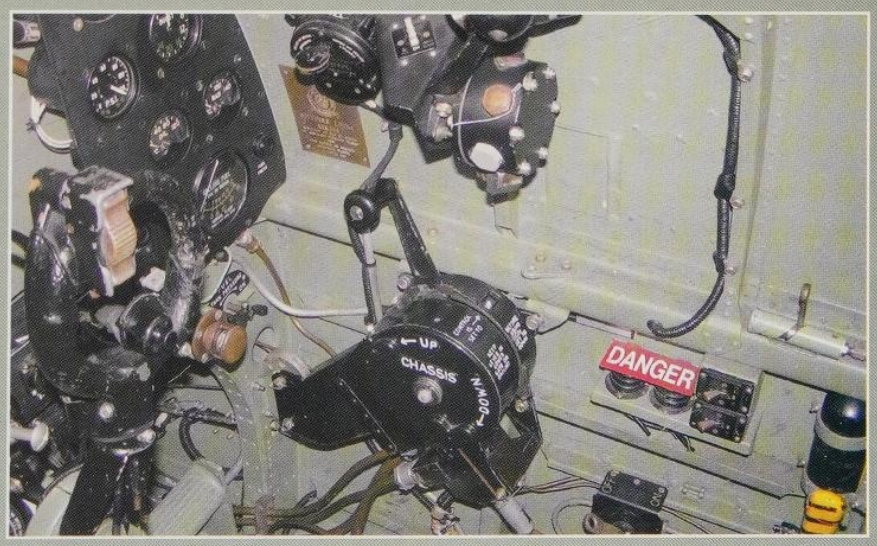
LEFT: The rear starboard cockpit of Mark IX MK356 showing the control locks in their stowage position. *(P. Blackah/Crown Copyright)*

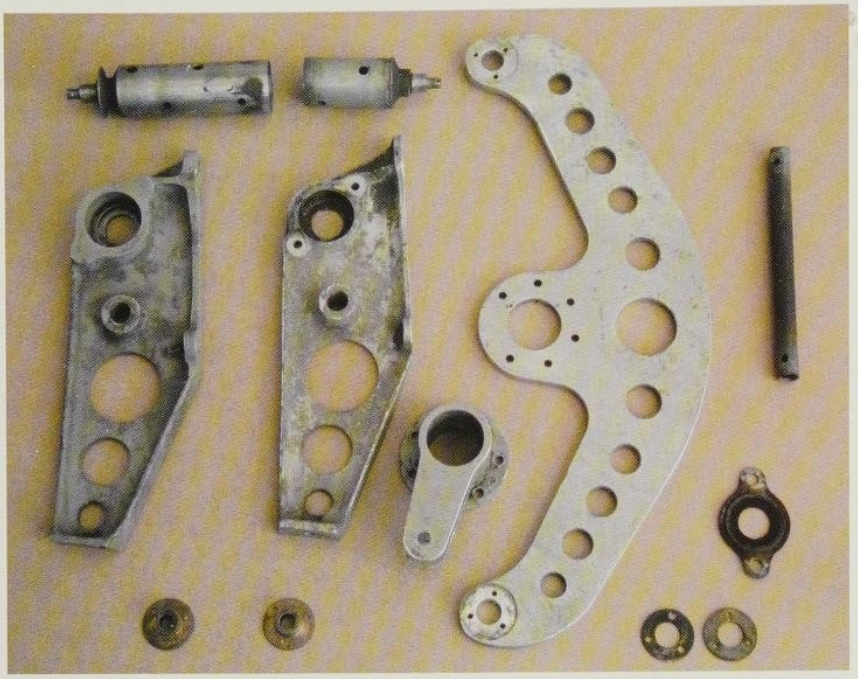


LEFT MIDDLE: The gun camera control located on the front port side of the cockpit on Mark XVI TE311. *(P. Blackah/Crown Copyright)*

LEFT BOTTOM: The throttle and propeller pitch controls located at the front port side of the cockpit on Mark IX MK356. *(P. Blackah/Crown Copyright)*

BELOW: Starboard side of cockpit of the Mark IX, showing the undercarriage selector in the centre. The object marked 'Danger' is the control unit for the R3067 identification friend or foe (IFF) equipment. This unit was fitted with detonators to destroy the coded reply settings, to be activated if there was a risk of the unit falling into enemy hands. The 'Danger' plaque is fitted to the aircraft for historical accuracy only: the IFF unit is not fitted to BBMF aircraft (nor are the detonators!).

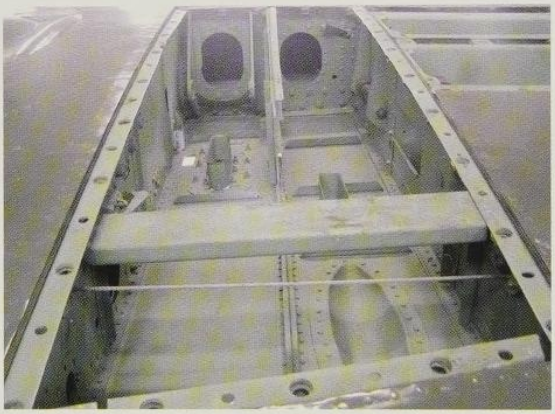




LEFT: A set of aileron bellcrank components removed from the wing prior to restoration. *(Airframe Assemblies)*

BELOW LEFT: Aileron bellcrank components in position in a wing with the skin removed awaiting refurbishment. *(Airframe Assemblies)*

BELOW RIGHT: A view of the cannon bay in the starboard wing of Mark IX MK356. The aileron control cable can be seen running across the bay in the foreground. *(P. Blackah/Crown Copyright)*



BELOW LEFT: The elevator (larger) and rudder (smaller) trim wheels on the port side of the cockpit of Mark XVI TE311. *(P. Blackah/ Crown Copyright)*

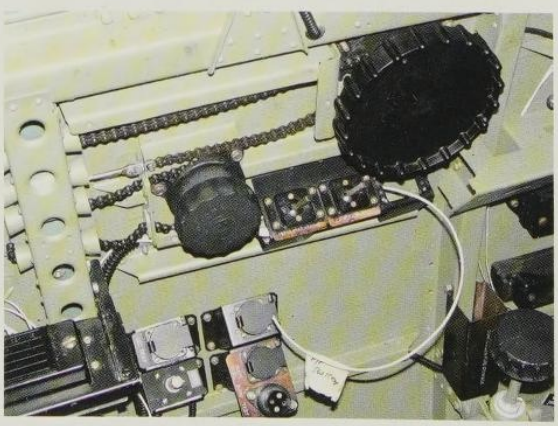
Flying controls

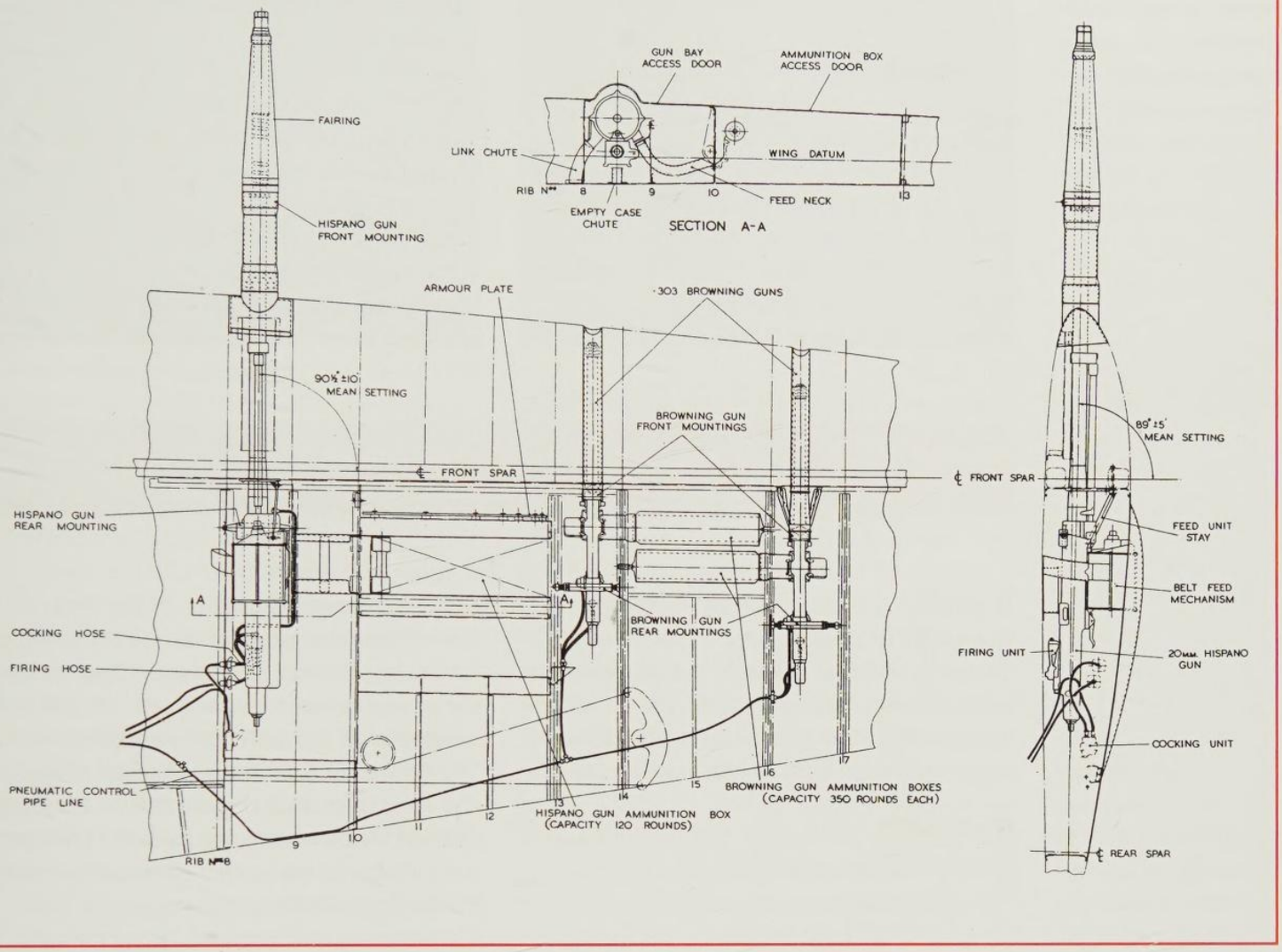
The aircraft's main flying controls are operated by a control column mounted in the cockpit, forward of Frame 10. The control column yoke operates the ailerons by means of chains and tie-rods connected to the aileron cable drum via a universal joint. The cables on the aileron drum feed out to the outer wing bellcrank, where an operating lever attaches to the ailerons. The ailerons have no trim tabs, trim being adjusted by bending the trailing edge of one or both ailerons slightly upwards or downwards.

The elevator is operated by the control column, via a rod that connects to a bellcrank fitted to main fuselage Frame 11. Cables run from this bellcrank down the length of the fuselage to another bellcrank in the tail unit. A second control rod connects this bellcrank to the elevator. Trim tabs are fitted to the elevator, one port and one starboard, and the trim tabs are operated by cables running to a large trim wheel on the port side of the cockpit. The amount of elevator trim is shown by a trim indicator on the instrument panel.

The rudder is operated by the rudder pedals, which move fore and aft on sliding tubes. Cables attached to these tubes run the length of the fuselage to a bellcrank assembly located alongside the elevator bellcrank. A control rod then runs from the bellcrank to the rudder. A trim tab is fitted to the rudder, operated by a small trim wheel on the port side of the cockpit.

FAR RIGHT: Looking back into the rear fuselage, showing the cables to the flying controls and trim tabs. From bottom to top: elevator control, rudder control, elevator trim, rudder trim. *(P. Blackah/ Crown Copyright)*





Weapons

Although not operative on Spitfires flying today, the guns were originally cocked and fired pneumatically from a firing button on the control column spade grip. Although some aircraft flying today are fitted with original or replica weapons, they are inhibited.

ABOVE: A diagram showing the installation details for .303 Browning machine guns and Hispano 20mm cannon. *(Crown Copyright)*

Dimensions and weights

Main dimensions

Note: *All figures given are for a Mk IX Spitfire, in flying attitude, datum line horizontal.*

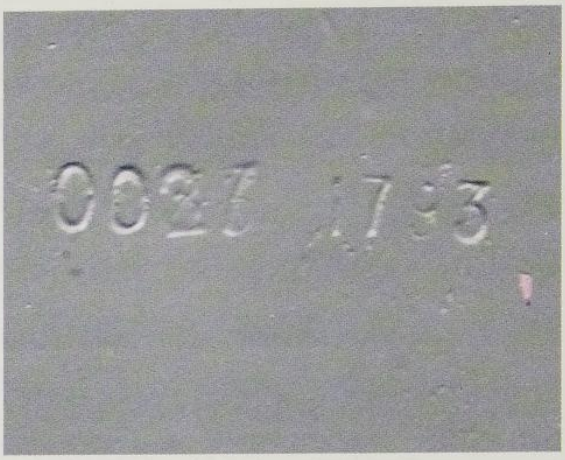
Wing span	36ft 10in (11.23m)
Overall length	31ft 0½in (9.46m)
Height to top of propeller	11ft 8in (3.56m)
Height to centre of propeller boss	6ft 3½in (1.92m)
Height to wing tips	5ft 4in (1.63m) approx

Weights

When operational, the Spitfire flew at a 'maximum permissible weight for all forms of flying' of 7,500lb (3,405kg). When fully armed and carrying drop tanks or bombs this maximum rose to 9,500lb (4,313kg), however this was for take-off and gentle manoeuvres only. Should the aircraft have difficulties, such as attack from another aircraft, the only course of action would be to jettison the drop tanks/bombs in order to achieve maximum manoeuvrability.

Most Spitfires now flying weigh between 5,500–6,500lb (2,497–2,951kg). This takes into account the loss of the armament, ammunition and items such as the armour plating, original radio and oxygen system.

Obtaining spare parts



RIGHT: The part number stamped into a section of armour plating. *(P. Blackah/ Crown Copyright)*

Airframe

Spitfire parts are identifiable by a five-digit number followed by a sheet number of up to a further four digits. The first three digits of the five-digit number identify the mark of Spitfire, the last two digits identify the system or area that the part is from. This system is used by both civilian and RAF personnel to source spares for all marks of Spitfire.

Examples:

30027/123 – 300 (Mark I)	27 (fuselage)	/123 (the actual part)
34945/456 – 349 (Mark V)	45 (fuel system)	/456 (the actual part)
36150/789 – 361 (Mark IX/XVI)	50 (undercarriage)	/789 (the actual part)

Engine

The system for sourcing engine spares is slightly different from that of the airframe parts. Merlin engine spares are predominantly prefixed with the letter D with up to five more digits, and Griffon engine spares are prefixed with the letters GN.

Examples:
D12345 – Merlin engine part
GN12345 – Griffon engine part

Pneumatic parts, hydraulic parts, wheels and brake parts

These parts are supplied directly from the companies, such as Dunlop, who give them their own unique part code.

The grapevine has become increasingly important

Those restoring Spitfires face continual worries that they will fail to find some critical item and it will be too expensive to manufacture a replacement. That has yet to happen, however, and Guy Black keeps a large collection of spares. Those he does not need for his own projects can serve as bargaining counters. In this business the currency of choice is spare parts, not money:

'As spares for Spitfires start to run short, the grapevine has become increasingly important. If you wanted to make new undercarriage legs, you'd have to build the forging dies to make them. That would cost a lot of money. Fortunately, though, Spitfire undercarriage legs are survivable items. Recently a scrapyard was being cleared and there were 60 pairs there. 'Things survive. After the war Spitfire wheels and axles were used on farm trailers. So scrap dealers put the wheels and axles to one side, because they'd get more money from farmers than selling them for scrap.

'Collectors up and down the country have shed-loads of Spitfire stuff. I have six barns packed with aircraft bits and pieces. I've got eight pairs of Spitfire undercarriage legs in one of my sheds. I collect this stuff because I never know when I'll need it. The great trick is to keep the stuff safe.'

The limits to authenticity

As important as the provenance of a Warbird aircraft is its degree of authenticity following restoration or rebuilding. And at this stage it has to be pointed out that no Spitfire currently flying is truly authentic. Modern product legislation, health and safety regulations and current flying operating procedures have seen to that.

Even the newest Spitfire airframe is more than half a century old. Unless the aircraft had

been parked in a hangar for much of that time, a degree of corrosion of the light alloy plating will have been inevitable. The afflicted areas will have been removed and replaced using equivalent modern materials.

In many Spitfires, the original rivets holding together the aircraft structure were made of magnesium alloy. That material is vulnerable to corrosion. On rebuilt Spitfires, all the rivets have been replaced with rivets made from hiduminium alloy, which has a far better resistance to corrosion.

Modern health and safety regulations prohibit the use of asbestos in the bulkhead or firewall of fuselage Frame 5 of early mark Spitfires (on late mark Spitfires this bulkhead is made of steel). The same goes for the original wartime instruments, with dials marked in luminous paint that contained radium and so was dangerous to handle. Over time the luminous paint on the dials will have deteriorated. The replacement dials of modern instruments look like the old ones, but they use a modern luminous paint that contains no radium. A further significant change to the instrumentation of most Warbird aircraft is that the airspeed indicators are calibrated in knots rather than miles per hour, to comply with modern navigational practice.

In any single-piston-engined Warbird with the pilot sitting directly behind the engine, there is a risk of carbon monoxide exhaust fumes entering the cockpit in flight. In extreme cases their presence can cause the pilot to lose consciousness, with fatal results. To guard against this, each restored Spitfire carries a modern carbon monoxide detector in the cockpit.

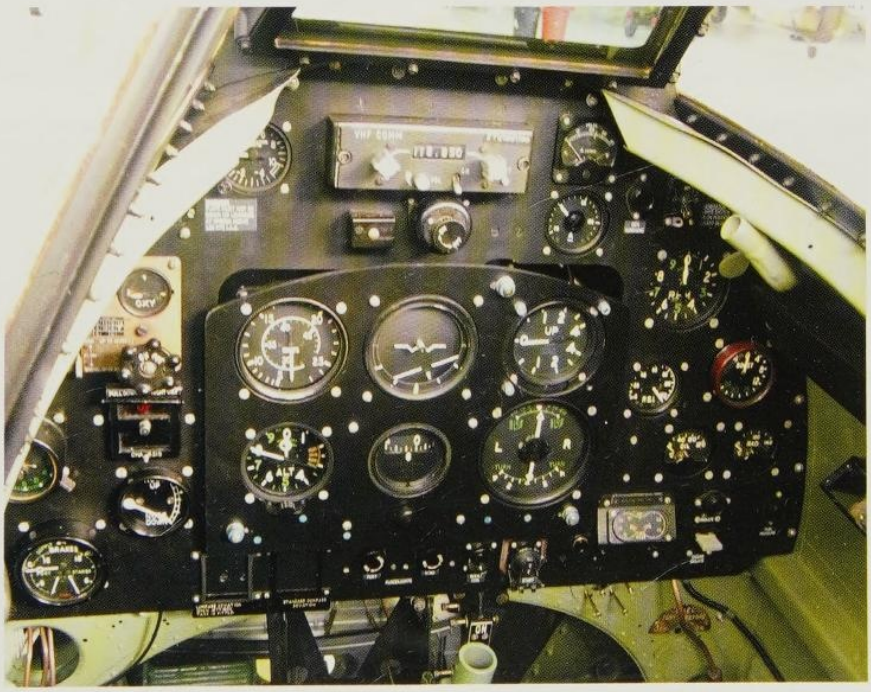
Wartime HF and VHF radio systems, using radio valves, are almost impossible to keep serviceable under modern conditions. So every flying Spitfire carries a modern solid state radio, of which a range of different types is available. The BBMF aircraft carry the Marconi AD 120 radio, which covers the civil VHF band and the military UHF band. As well as a radio, modern air traffic control legislation decrees that aircraft flying in controlled airspace must carry a radar transponder to identify them on ground surveillance radars.

Normally, Warbird Spitfires have no reason to climb above 10,000ft, so most have their original oxygen systems rendered inoperative, though in the majority of cases the oxygen cylinders remain in place.

LEFT: The corroded and damaged lower cockpit skin taken from Mark XVI TE311. The metal was in poor condition and it was replaced. *(P. Blackah/ Crown Copyright)*

The great majority of Spitfires were built with 12v electrical systems, though Spitfire 24s and Seafire 47s had 28v systems. During the restoration process most Warbird Spitfires with 12v systems had these upgraded to 28v and fitted with modern alkaline batteries. The extra power from the latter allows the engine to be started using the aircraft's internal battery. That removes the need for an accumulator starter trolley, which may or may not be available if the aircraft lands away from its home airfield.

The original electrical wiring in Spitfires used resin insulation coating, which deteriorated with time. During restoration this will have been replaced with modern wiring that has more effective and longer-lasting plastic insulation.



BELOW: The instrument panel of Mark XVI TE311, showing the modern-day Marconi radio unit (centre top). *(P. Blackah/Crown Copyright)*

The Spitfire industry

Initially just a few workshops engaged in patching up Spitfires to return them to flight, manufacturing small replacement parts as required. But there were limits to the amount of patching that an aircraft can take before a major overhaul became essential. So in the early 1980s there arose a demand for larger replacement items for Spitfires, such as fuselage frames, cowlings, ailerons, elevators and rudders.

That in turn led to the formation of a clutch of small specialist companies to perform this work. Typical of these were Historic Flying Ltd (HFL) at Audley End, later at Duxford; Airframe Assemblies at Sandown on the Isle of Wight; and the Aircraft Restoration Company (ARCo) at Duxford. Elsewhere, Spitfire airframes were being restored in garages by one or two engineers indulging in their labour of love in their spare time. To complement this airframe reconstruction work, Retro Track and Air at Dursley in Gloucestershire has made a speciality of restoring aero engines, including Merlin and Griffon engines for Spitfires. And in the USA a number of companies are engaged in restoring Merlin engines, mainly for installation in P-51 Mustangs.

One of the first steps in any restoration project is to get hold of the relevant RAF manuals. The manual on the Spitfire is 'Air Publication 1565'. AP1565A relates to the Mark I, AP1565B relates to the Mark II, and so on. Volume III Part 2 of each publication is the spare parts schedule. This has few pictures and the descriptions are in back-to-front-military-speak, like 'casting, machined, bracket, aileron'. Fortunately, works drawings still exist for many of the components.

When a Spitfire undergoes a major renovation its airframe is first stripped down to sizeable assemblies. Then it is reduced to individual components, which are labelled and photographed. These components are carefully cleaned and checked for surface corrosion, and are measured to determine whether their dimensions are within acceptable limits. They are also visually inspected for cracks. Next, one or more of the non-destructive tests (NDTs – see box on page 93) is carried out on the component, to check for internal cracks that might have got past the visual inspection.

Components that pass through these processes satisfactorily can be used in the refurbished aircraft. Those that are stretched beyond their laid-down limits, or are cracked or corroded, will serve as patterns for the manufacture of their replacements. To restore an engine there is a similar process of stripping down to individual components, cleaning, measuring and non-destructive testing, and then reassembly using replacement parts where necessary.

Today the companies mentioned above are all thriving businesses, with highly professional workforces numbering between 12 and 45 and comfortably full order books. And although this book concerns itself only with Spitfires, it should be pointed out that these companies can also resuscitate other types of Warbird.

BELOW: In 1991 Mark Parr came to Duxford to overhaul an oil tank for Historic Flying Ltd. He has been with the company ever since. He is pictured working of the wing fillet of Mark XVI RW386 during its restoration at HFL. *(Alfred Price Collection)*

BELOW RIGHT: Peter Watts, proprietor of Retro Track and Air, pictured with a refurbished Merlin engine nearly ready for delivery. *(Alfred Price Collection)*

Some pitfalls to avoid when restoring a Spitfire

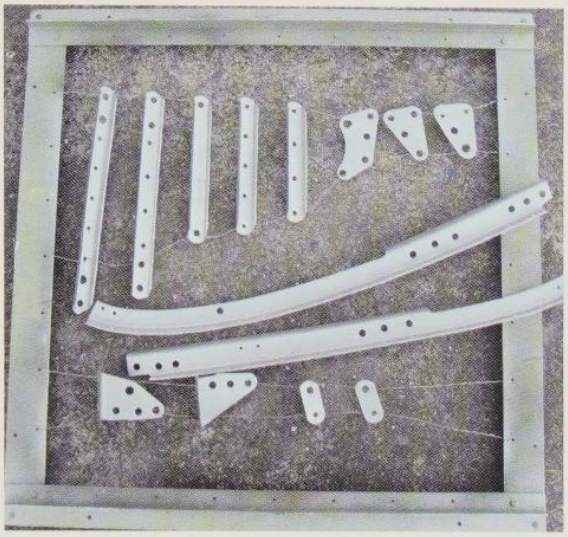
Guy Black of Aero Vintage Ltd describes some of the pitfalls he learned to watch out for when he began restoration work on a Spitfire IX:

'With restoration work, as I had learned from the car world, there's nothing worse than somebody presenting you with 45 broken cardboard boxes containing all the bits. You don't do that. With a damaged airframe, you have basically a pattern to build a new aeroplane. If you can include in it used parts that are as good as new, all well and good.

'We started dismantling one wing, and we did it very carefully. To inspect the spars we had to dismantle it completely. But the leading edge of the Spitfire wing, the D-box, comes away in one piece. And the trailing edge, similarly, comes off in big chunks. We took one wing apart, in big chunks, and restored one big chunk at a time. That was the key to saving the information.

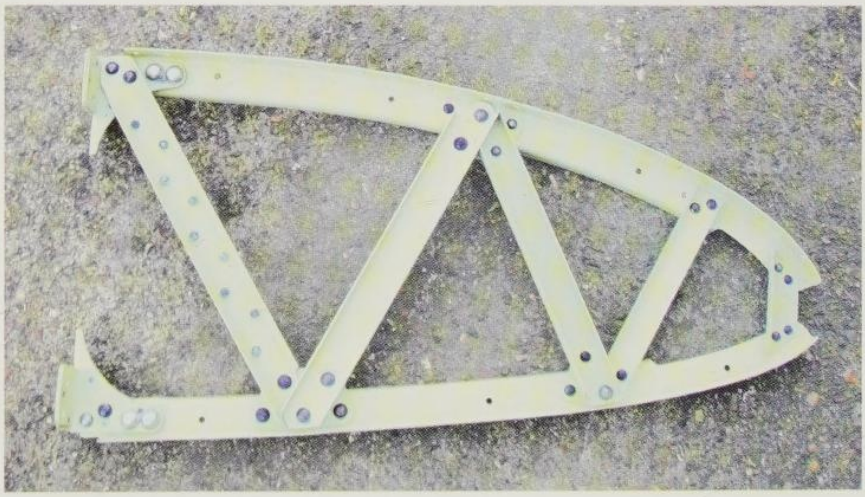
'Having inspected the wing spar booms, I thought there was nothing wrong with them. A company called Trent Aero had developed the technology to produce new Spitfire wing spar booms. One of their people came to see me and he suggested I should replace the spar booms, because of possible corrosion there. He said there might be internal damage that couldn't be seen from the outside, even though an X-ray of the structure looked promising.

'He persuaded me to put in new spar booms, and I'm glad he did. Afterwards, for curiosity, we cut up one of the original booms and found to our horror that the inside had corroded almost to nothing. Whenever the guns had been fired, highly corrosive cordite fumes had streamed back into the wing structure.'



ABOVE RIGHT: A corroded and damaged wing section, which will be replaced with new components during rebuild. *(Airframe Assemblies)*

ABOVE LEFT: A wing D-section nose rib kit ready for assembly. The components have just been sprayed, which is why they are attached to a support frame by thin wires. *(Airframe Assemblies)*



RIGHT UPPER: A newly assembled wing D-section nose rib. *(Airframe Assemblies)*

RIGHT: Various new wing components primed and ready to fit. During spraying, the components are supported on thin wires in the metal frames shown. *(Airframe Assemblies)*

ABOVE: After the war Spitfire IX PV202 was modified into a two-seat trainer for the Irish Air Corps, in which service it carried the side number 161 on the fuselage. *(Jim Masterton)*

BELOW: The sad sight of PV202 pictured after its fatal landing accident at Goodwood in April 2000. *(Steve Moss)*

Damaged, repairable...

No two aircraft restoration or repair projects are the same, but that of the ex-Irish Air Corps Mark IX two-seater No 161 can be regarded as one of the more far-reaching. This Spitfire suffered extensive damage in an accident in April 2000. John Romain describes the accident and the condition of the aircraft when it arrived at Historic Flying Ltd at Duxford for repair:

'It stalled on the landing approach into Goodwood. The port wing dropped, hit the ground and tore off. Then the rest of the aeroplane flipped on to its back. The tail section broke off, and the top of the fuselage was pretty much flattened. So it was very badly damaged.

'The wreckage was bought for something over £100,000. But for that we got a lot of parts we could reuse. If you look at the price of aircraft parts now, it doesn't take a lot to get £100,000's worth from the wreckage. Basically there was a complete aeroplane, though obviously one that was badly damaged.

'During the crash the undercarriage legs did not hit the ground, because the port wing had taken the shock of the landing. The undercarriage system, the undercarriage legs, they were reused. The whole of the starboard wing was reused.

'They changed the wing spar booms, because it was an ideal time to do it. When you strip

Restored to its original Irish Air Force colours, PV202 returned to the air in September 2006. *(Peter R. Arnold)*

a wing down to its last component, that is an ideal time to put in a new wing spar. You wouldn't want to have the original spar in one wing and a brand new spar in the other. But the rest of it, the aileron, the wing tip, they were from the original aeroplane.

'The resultant machine is not a new aircraft; it is a crashed aircraft that has been repaired. If you can salvage parts from a crashed machine, as long as they go through proper inspection, repair and overhaul facility, there is no reason you shouldn't use them. Spitfire 161 has been flying again for a year and a half.'

Rebuilding Spitfire P9374

John Romain at the Aircraft Restoration Company describes the recovery of Spitfire P9374 from the sand flats off Calais, after several decades in the sea:

'That Mark I did a wheels-up landing on the beach off Calais. It's surprising. Now the feelers have gone out and people know we're going to restore it, we get calls from people in France who have bits off that aeroplane. We'll end up with quite a substantial project. We have the front fuselage, with much of the cockpit forwards including the engine. One tailplane has shown up. The outer wings, pretty much out from the undercarriage bay, they were in a barn in France, a collector has them. We know where the original guns are. Restoring it to flight will be a big engineering project, but we love those.'

Chris Michel from Airframe Assemblies Ltd expressed his enthusiasm to begin work on the restoration of P9374:

'That Mark I, we look forward to getting our teeth into it because the quality is pre-war Supermarine. All the bolts and fittings are made of stainless steel and other parts were anodised, to prevent corrosion. Later in the war they didn't bother, most Spitfires didn't last all that long. They used parts made of carbon steel that weren't plated, they became all rusty and horrible. Those are what we usually have to deal with.

'This Spitfire has the lovely early rudder pedals with "Supermarine" in scrolled writing on them. They look gorgeous. Everything about the aircraft is lovely pre-war quality.

'The aircraft lay buried in the sand, and the water stayed on top of the sand. It excluded the oxygen and that was obviously a great preserver. The anodising of the parts also helped prevent corrosion. The French Army took the machine guns, and after a clean-up they had them firing again on the range. We've tracked down three of the guns in a museum, and with a bit of luck the deactivated guns can go into the restored aircraft. Everybody wants them to go in there. The watchword is to keep the aircraft authentic, keeping as many original parts as possible.'

LEFT: Considering their lengthy immersion, some items from P9374 had survived surprisingly well. John Romain, proprietor of the Aircraft Restoration Company (ARCO), pictured with some items of pipework taken from the aircraft. *(Alfred Price Collection)*

Non-destructive testing, an invaluable tool

Four methods of non-destructive testing (NDT) are available: an X-ray check, an ultrasound check, a magnetic particle check and a dye penetrant check.

The X-ray check is used to examine parts of the Spitfire that cannot easily be accessed, such as the main spars and the engine bearer tubing. The X-ray check will usually show up any internal corrosion or cracking, though very careful examination of the results is necessary (see 'Some pitfalls to avoid when restoring a Spitfire' on page 91).

The ultrasound check uses sound waves to detect cracking around the bore of a hole. A probe is inserted into the hole, for example a spar hole, and a meter readout indicates if there are signs of damage in the vicinity of the hole.

The magnetic particle check is used to look for cracks in ferrous metal components. The component is painted with a fluid containing iron filings, then an electric current is passed through it. The sample is then examined under ultraviolet light, which highlights any faults. Afterwards, the sample is demagnetised.

The dye penetrant check is used when looking for cracks in ferrous and non-ferrous metal components. The component is painted with fluorescent purple dye, then cleaned and sprayed with a white developer. After a wait of about 40 minutes the component is examined and any cracks will be highlighted in purple.

'Though it is a great privilege to be the owner of a Spitfire, there is also a childish delight in being in possession of this beautiful object.'

Guy Black,
Director, Aero Vintage Ltd

(Photo: Peter R. Arnold Collection)

Chapter Three

The owner's view

There are four ways a private individual can obtain an airworthy Spitfire: by purchasing one; by restoring or repairing a dilapidated airframe; by rebuilding a wrecked aircraft and incorporating some pieces from the original aircraft to provide a provenance; or by building an all-new reproduction Spitfire incorporating no parts from an original machine.
This chapter examines these alternatives and considers their pros and the cons.

RIGHT: Restoration of the fuselage of Mark XVI TE311 in progress with the Battle of Britain Memorial Flight at Coningsby. *(P. Blackah/Crown Copyright)*

To purchase an airworthy Spitfire

Although this is the easiest way to obtain one of these aircraft, it is still not a simple matter. Even if you have the necessary dosh to spare – and you will need about £1.4 million to be in with a chance – a Spitfire is not the sort of thing you pick up on eBay.

As with any antique, and other things being equal, the older the object the greater the price it will command. In the case of a Spitfire or a Seafire, a low mark number with the original high back rather than the later low back and teardrop canopy, powered by a Merlin engine rather than a Griffon, are features that will increase its rarity value. This will be reflected in the aircraft's market price and its availability.

The converse is also the case. A low-backed Spitfire XIV or XVIII, powered by a Griffon engine and with no combat record, will be somewhat cheaper and easier to obtain.

Purchasing is the easiest and least stressful way to obtain an airworthy Spitfire. Now let us look at some of the others.

To restore or repair a dilapidated or badly damaged airframe

The next alternative is to buy a dilapidated or a seriously damaged airframe, and either restore it to flying condition or pay someone else to do so. The trouble is, the Spitfires that had been employed as gate guardians at RAF stations, or had sat in kibbutz children's playgrounds, or had lain derelict beside Indian Air Force airfields have long-since been snapped up and put into the restoration process. It is possible there are still some Spitfire airframes lying undetected at disused airfields in some remote part of the world, but, like the legendary Eldorado with its reputed hoard of gold, people have spent years searching without success.

However, assuming you are successful in finding a dilapidated airframe, that will be only the start of your problems. To get an impression of the scale of the deterioration that is likely to have taken place, let us look at the example of Spitfire XVI TE311. At the time of writing this aircraft is

The engine cowl of TE311 in the condition in which it arrived at BBMF, showing light corrosion and a covering of dirt... *(P. Blackah/Crown Copyright)*

...and after restoration and some tender loving care, following cleaning and minor repairs and the fitting of new fasteners. *(P. Blackah/Crown Copyright)*

undergoing a lengthy restoration in the Battle of Britain Memorial Flight hangar at Coningsby.

In its previous existence this Spitfire had been a gate guardian at the RAF stations at Tangmere and Benson. Then it spent several years with the RAF Exhibition Flight. The latter role involved frequent transportation by lorry. On arrival the aircraft was assembled and left in the open until the exhibition or other event ended. Then it was dismantled and returned to RAF Abingdon, to await the next event. Over time, that process of repeated assembly and dismantling, and frequent transportation, had taken its toll.

The state of TE311 when it arrived at Coningsby was typical for a machine that had suffered years of neglect. One particularly bad area of corrosion was to the engine bearers. These were weakened to such an extent that it was possible to grasp the engine and push it from side to side. There was another bad area of corrosion below the cockpit.

Other areas had suffered less extensive though still serious damage. Sunlight had caused the exterior finish to fade and parts of the Perspex canopy had become opaque and brittle. Rainwater had entered the airframe through panel seams and the canopy, causing damage to untreated metal areas. The engine exhaust stubs had corroded. The flying control surfaces – the ailerons, the elevators and the rudder – had crude aluminium alloy plates riveted on to lock them in the neutral position. The propeller blades, made of laminated spruce, had started to delaminate.

Yet, surprisingly, the original Packard-built Merlin 266 engine had survived well enough to be judged suitable for restoration. After careful checking and non-destructive testing much of the original structure has been found suitable for reuse. This is essential to establish the provenance of the Spitfire when it is completed (about which more later). Even those parts judged unsuitable for reuse could serve as patterns for the manufacture of their replacements.

To rebuild a wrecked aircraft

The planned rebuild of a Spitfire Mark I, P9374, is a quite different order of restoration to that of TE311. P9374 was delivered to No 92

BELOW: On 24 May 1940 this Spitfire I, P9374 of No 92 Squadron, suffered severe damage in combat with Messerschmitts and made a wheels-up landing on a sandbank off the French coast near Calais. It is seen being examined by German military personnel. Then the shifting sands of the Strait of Dover moved in to cover it, until only one propeller blade protruded from the water. *(Peter R. Arnold Collection)*

ABOVE: In 1980, after some 40 years, the shifting sands moved again to reveal much of P9374. Restoration began in May 2006, incorporating as many of the aircraft's original parts as possible. *(Xavier Portier)*

OPPOSITE TOP: Aviation historian Andy Saunders, centre, examining some of the wreckage brought ashore from P9374. *(Peter R. Arnold Collection)*

Squadron in March 1940. On 24 May – the day before the start of the Dunkirk evacuation – it suffered a hit from a cannon shell in the cooling system during a combat with Messerschmitts. Pilot Officer Peter Cazenove made a wheels-up landing on a sandbank off the coast near Calais, waded ashore, and spent the rest of the war in captivity.

Then the shifting sands of the Strait of Dover moved to cover the aircraft, and it remained hidden for the next four decades. In the winter of 1980–1 the sands shifted again, to reveal much of the aircraft. Parts were brought ashore and, considering their lengthy immersion, some had survived surprisingly well.

In May 2006 Historic Flying Ltd at Duxford received a contract from a customer in the USA to rebuild P9374. Airframe Assemblies at Sandown will build the fuselage, wings and tail, incorporating as many of the original parts as possible. Then assembly and installation of the engine and the various systems will take place at Historic Flying Ltd.

The proposed rebuild of P9374 has evoked considerable interest in the Spitfire Warbird community, and it raises the important question: just how much – or how little – original material is required to guarantee the provenance of a Spitfire? And are we about to see a series of wrecks being dug out of the ground and restored to flight in the same way?

To build a replica Spitfire

Why go to the expense and bother of acquiring parts from the buried wreckage of an aircraft, few of which will pass inspection and be suitable for incorporation in the new aircraft? It is as easy to manufacture a new Spitfire from scratch, as to restore the airframe using a token spread of original components. The resultant aircraft would look like a Spitfire, it would sound like a Spitfire, it would even smell like a Spitfire. Would that not make it a Spitfire?

The short answer is 'No'. The resultant aircraft will have no history or provenance. It would be, in effect, a 'second-class Spitfire'

and its resale value would be reduced accordingly.

Following the example of P9374, there are scores of Spitfire wrecks around the world whose location is known and which could be dug up to provide parts to give provenance to a rebuilt aircraft. This process will have a long way to go before it is played out.

'It was done by word of mouth'

Guy Black, one of the Directors of the Historic Aircraft Collection (HAC), described how he part-exchanged his Spitfire IX for a Mark V – an aircraft with a greater rarity value – that his company had been keen to acquire:

'One day Tim Routsis [from Historic Flying Ltd] rang me and said "I hear you might sell the Mark IX. If you do, that will enable you to buy my Mark V. I know a man who wants a Mark IX." That was how it happened, it was done by word of mouth. There isn't an *Exchange and Mart* section on Spitfires, it is a world where everyone knows everyone else. Our Mark IX went to Andrew Torr in South Africa, and we acquired Tim's Mark V.

'In a way all Spitfire restorations are reproductions; you have to change so much. [Many] original Spitfires were made with those wretched magnesium rivets, which destroyed everything they were attached to.

'Our Spitfire V [ex-gate guardian BM597] was a complete aeroplane, but HFL still had a lot of problems with it. I would doubt whether more than 25 per cent of the original structure is in the aircraft you see out there today. If it was one per cent it's still the original aeroplane because that aeroplane existed, complete, before the work started. So what we've done in effect is a maintenance programme which involved replacing almost everything. I know that sounds strange, but if in the RAF you had a wing destroyed, you'd replace it with another wing. So today we're doing the same sort of major servicing that was done at the time. Except, we ended up replacing most of the metalwork on the aircraft.'

The unsuitable would-be purchaser

Owning a Spitfire is a game only for the seriously rich. In his time John Romain has sold numerous Spitfires. As he explains, several would-be purchasers who contact him do not realise the demands such a purchase will make on their finances:

'We get a lot of phone calls from people who say they'd like to buy a Spitfire. With many of them we know, instantly, there is no way they are ever going to get one. They might be used to the general aviation market, say with a Cessna 150. There the maintenance costs maybe £6,000 per year, insurance maybe £2,000, and it burns a couple of pints of fuel per minute. Now they're considering the Spitfire, where maintenance costs are £25,000 to £30,000 per year, insurance might cost another £50,000, and it burns a gallon of fuel per minute. And the price of an airworthy Spitfire with a good provenance is around £1.4 million. Suddenly all these figures start dancing around in the guy's head and he says "Hum, well, I didn't quite think it would cost that much."'

When John has a Spitfire for sale, his secretary informs each of the people on his list who have expressed an interest in it, and have shown an ability to purchase it. Then the haggling starts.

The question of provenance

Provided the aircraft's serial number can be found or determined, then the provenance of a Spitfire can be established. The serial number was stencilled externally on the rear fuselage, and internally on the front lower part of the firewall, Frame 5 of the fuselage. Some aircraft also had the number stencilled or stamped on the front upper fuel tank. Checking the serial number against that aircraft's Form 78, the individual record card (most of which are now held at the RAF Museum at Hendon) will reveal the salient points of the aircraft's service history. Further research in the war diaries of the squadrons with which it flew, held at the National Archives at Kew, will establish the aircraft's career in action.

Now the issue of provenance raises its head. Merely painting a serial number on the rebuilt aircraft is not enough. In Great Britain the practice concerning provenance follows that long established with classic cars. Provided some parts established to have come from the original aircraft are built into the reconstructed machine, that gives it the required historical thread of provenance. Without the incorporation of those pieces, no such thread exists. That begs the question, how much incorporated material is necessary to provide an aircraft with the required historical thread? The normally accepted answer is 'A reasonable portion of fuselage primary structure, from an original aircraft with an established provenance'. The definition of 'reasonable', in this context as in many others, is open to negotiation (one wonders what 'our learned friends' would make of that, if they ever got the chance).

The bottom line

As stated above, to produce an airworthy Spitfire airframe using a spread of salvaged components and the rest newly built, and an overhauled engine, requires several man-years of work. Give or take, a refurbished Spitfire of good provenance costs around £1 million to build and it might sell for around £1.4 million. The margin between the cost of rebuilding a Spitfire, and its value afterwards, is not as great as that might suggest however. Not if one considers that such a project might take five years or more to complete, and incur large financing costs. Also, a prospective buyer needs to consider what that amount of money could make if, instead, it was invested in the normal way on the stock market. One thing is certain: investing in a Spitfire restoration project has little to commend it as a purely money-making proposition.

The inevitable paperwork

An old flying adage tells us that when the weight of the paperwork equals the weight of the aircraft, the latter is ready to fly. Although that is an exaggeration, those concerned professionally with aviation will attest to the statement having the ring of truth. To put a restored Spitfire back into the air, certain legal hurdles have to be negotiated.

During the restoration, the engineers concerned assemble a work pack that records every hour of work done on the aircraft, and lists the parts incorporated in it. Only companies approved and licensed by the Civil Aviation Authority (CAA) are permitted to carry out this work. When the

restoration is finished and the work pack is complete, the senior engineer writes an E4 Report giving an overview of the work done.

Then the aircraft receives an Airworthiness Approval Note, form AA20, which allows the user to maintain and restore the aeroplane to flying condition. When it is ready to fly the CAA issues a Permit to Test (PTT), which allows it to be test flown. Normally the PTT lasts for one month and allows for five hours' flying, though these limits can be extended if required. If the flight tests go smoothly, the Flight Test Schedule is produced and presented to the CAA. If approved, it becomes the basis for the flight manual. The owners are also required to design a maintenance schedule, which has also to be approved by the CAA.

A Warbird aircraft does not receive a Certificate of Airworthiness. Instead it receives a Permit to Fly (PTF), which needs to be renewed annually. Many Warbird aircraft could, in theory at least, be restored to fighting trim and even carry weapons, so to reduce the risk of abuse the PTF carries certain restrictions. It is strictly a national document, which means it does not give permission for the aircraft to fly through another nation's airspace. Each such venture into foreign airspace must have prior formal permission from the nation concerned. Also it is prohibited from flying at night or in instrument flying conditions, for which it is not equipped. Nor is it permitted to carry fare-paying passengers, even if the aircraft has the necessary seating.

Insurance

Strictly speaking, the law does not demand that an aircraft should carry insurance. However, to be allowed to fly from any airfield managed by the Crown Agents, for example Duxford, an aircraft must have third party insurance to the value of £50 million. That is relatively inexpensive at around £4,000 per year.

The really expensive item is if one wants to insure the hull of an aircraft. If a Spitfire's value is set at £1.4 million, and the owner wants to insure it against total loss, the Lloyd's underwriters will quote a rate of around 4 per cent. Four per cent of £1.4 million pounds is £56,000. So if the Spitfire flies about 25 hours per year – which is around the average for a privately owned aircraft – that works out at £2,240 per flying hour just for insurance. Gulp!

Faced with this teeth-sucking arithmetic, many owners choose not to insure their aircraft hull for its full value. Their argument runs like this: 'If once every four years the aircraft suffers moderate but repairable damage, it will cost less to repair it than the £224,000 outlay for the insurance premiums over that period.'

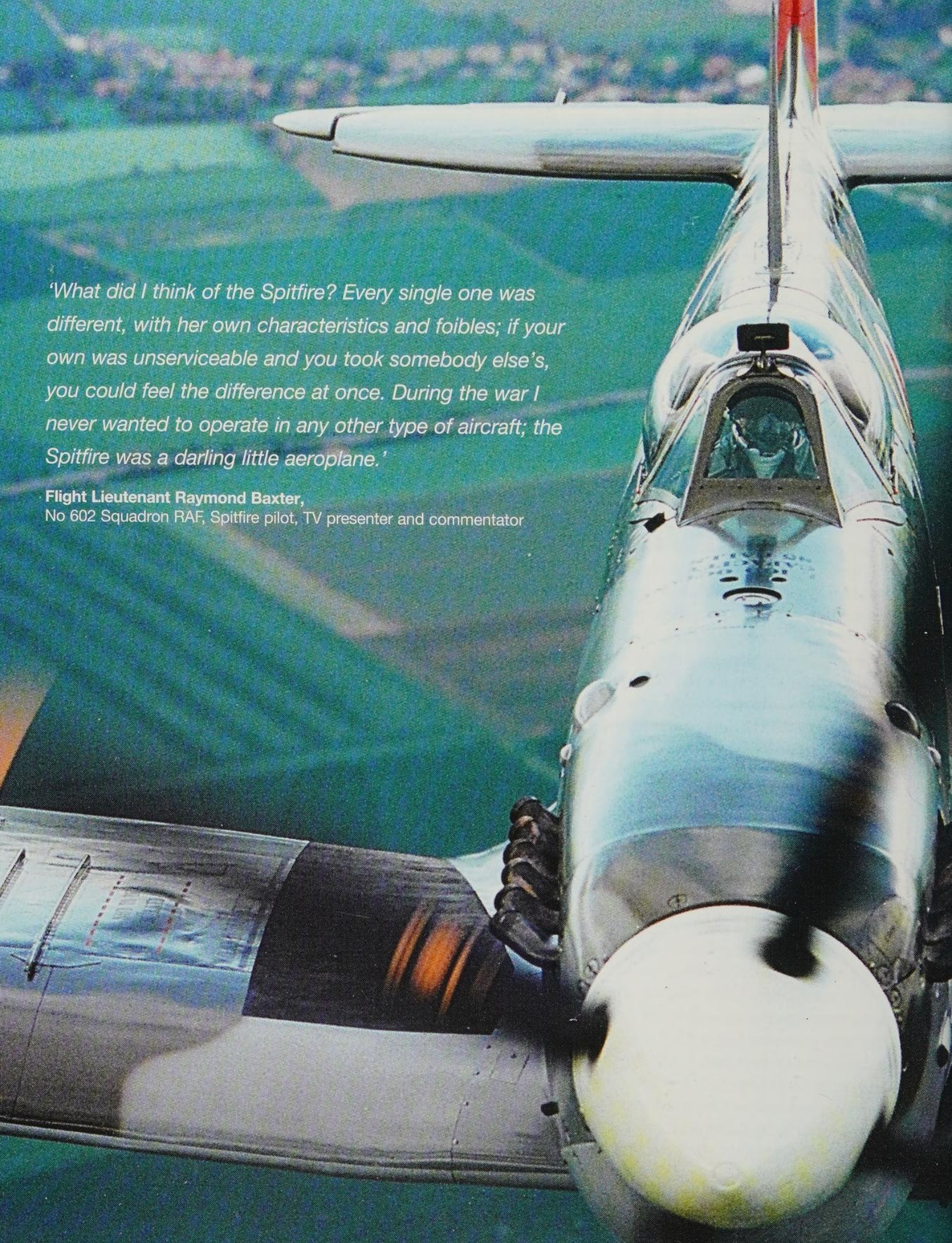
Running costs

Having acquired a Spitfire, that is just the start of the expenses. For your new pride and joy lives in a world where nothing comes cheap. To name just a few 'sundry expenses' that will appear on the balance sheet from time to time, a main-wheel tyre costs £385 and lasts about 30 landings; a tail wheel tyre costs just under £300; a propeller hub costs around £30,000; a single propeller blade costs around £6,500 (ironically these are manufactured in Germany, by Hoffmann GmbH at its factory near Munich); and to overhaul a propeller that does not require a replacement hub or a blade costs around £10,000.

At the time of writing, oil (W100 or OM270) is approximately £11 per gallon and the average oil tank holds 9½ gallons. The engine burns between one and nine pints per hour, and the oil level is topped up after each flight. At 25 hours' flying the oil system is totally drained and replenished.

Again at the time of writing, fuel (Avgas) is £1 per litre (£5 per gallon) and a Spitfire Mark IX holds, in its main tanks, 85 gallons, which equates to approximately two hours' flying time.

LEFT: A pair of main wheels showing wear on the tyres – each tyre lasts for around 30 landings if the aircraft is flown from hard runways. *(P. Blackah/ Crown Copyright)*



'What did I think of the Spitfire? Every single one was different, with her own characteristics and foibles; if your own was unserviceable and you took somebody else's, you could feel the difference at once. During the war I never wanted to operate in any other type of aircraft; the Spitfire was a darling little aeroplane.'

Flight Lieutenant Raymond Baxter,
No 602 Squadron RAF, Spitfire pilot, TV presenter and commentator

(Photo: Crown Copyright)

Chapter Four

The pilot's view

From the time it entered service, the Spitfire gained a solid reputation as a pilot's aeroplane. With a skilled pilot at the controls, it could perform with all the subtlety and sureness of touch of a prima ballerina. At the other extreme, handled by inexperienced pilots who lacked the training or the flying hours to know better, it would stoically accept all manner of indignities yet still bring them safely home. The purpose of this Chapter is to put the reader 'in the cockpit', to get the feel of what it was like to fly the aircraft both in war and in peace.

BELOW: Current MoD Form 724, which acts as an aircraft Flying Log for the BBMF's Spitfires. Each aircraft has its own Flying Log, and details of all flights are logged, with running total of hours flown, number of landings and flying hours since winter maintenance. *(P. Blackah/Crown Copyright)*

In its day the Spitfire was a state-of-the-art fighting machine, and any aspiring pilot found himself at the bottom of a precipitous learning curve. He needed to gain a sound knowledge of every aspect of the aircraft and its various systems. He needed to develop a sureness of touch with the controls to enable him to take the aircraft up to – but never beyond – its aerodynamic and structural limits. And he needed to be adept in the unrelated but important skills of instrument flying, navigation and gunnery.

Oh yes, and then there was the business of 'the Hun in the sun'. In areas where the enemy might be encountered, for about 55 seconds in every minute the Spitfire had virtually to fly itself. Because during that time the pilot's eyes were outside the cockpit, conducting a systematic all-round search for the enemy. The majority of pilots shot down in air-to-air combat never saw the attacker before their aircraft shuddered under the impact of hits. Whatever the romantics might have one believe, air fighting was a rough and nasty business, with no quarter asked or given. All too often 'a sitting duck' became 'a dead duck'.

Peacetime flying in the Spitfire is another matter altogether. The chances are that today's 'Hun in the sun' will buy you a beer after you both land. That said, there are traps a-plenty for the over-confident, the undertrained or the underbrained pilot. This thoroughbred needs to be treated with the greatest respect throughout every phase of the flight. Or, as an old flying adage puts it: 'You control the aircraft, otherwise the aircraft will control you.'

MOD Form 724(Historic Single) (Revised Feb 93)

Flying Log and Equipment Running Log

Aircraft Type SPITFIRE Mark IXe Serial No MK 356 Sheet No 24

Flight No	Date	Flight Times: Take-Off	Landed	Duration	Aircraft Total Hours	Landings: Roller	Full Stop	Total	SPC	Station of Landing	Name of Captain (Print)	Flying Hours Since Winter Maintenance
	B/F Totals				267:20			356				29:30
1	13 Sep 06	15:25	16:05	:40	268:00		1	359	14	NORTHOLT	PINNEL	30:10
2	14 Sep 06	13:00	13:55	:55	268:55		1	360	13	NORTHOLT	PINNEL	31:05
3	14 Sep 06	18:15	19:05	:50	269:45		1	361	14	NORTHOLT	PINNEL	31:55
4	15 Sep 06	18:35	19:20	:45	270:30		1	362	14	— " —	— " —	32:40
5	16 Sep 06	16:20	17:15	:55	271:25		1	363	14	CONINGSBY	PINNEL	33:35
6	22 Sep 06	18:45	19:00	:15	271:40		1	364	13	— " —	JASON	33:50
7	24.09.06	16:35	15:55	1:20	273:00		1	365	13	— " —	ROWLEY	35:10
8	4.10.06	16:10	16:20	0:10	273:10		1	366	12	— " —	JASON	35:20
9	8.10.06	08:35	09:00	0:25	273:35		1	367	14	DUXFORD	JASON	35:45
10	8.10.06	16:00	16:40	0:40	274:20		1	368	13	CONINGSBY	JASON	36:25
11	12.10.06	16:00	16:10	:10	274:30		1	369	12	CONINGSBY	PINNEL	36:35
12	14.10.06	14:10	14:20	:10	274:40		1	370	12	— " —	PINNEL	36:45
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Totals				:								:

Sortie Profile Codes (SPC) Select code which most closely descibes your flight

10 Air Test	11 Training	12 Display Only	13 Transit & Display	14 Transit Only
20 Air Test	21 Training	22 Display Only	23 Transit & Display	24 Transit Only

Although the ground crew do specific pre-flight checks, there are set procedures for the pilot to follow from pre-flight walk round checks to take-off and landing checks.

Start-up

The following photographs show the step-by-step procedure for starting the engine on a Mark IX Spitfire.

1 The throttle control is set to the start-up position. *(P. Blackah/Crown Copyright)*

2 The radio transmit button is depressed to talk to air traffic control to seek clearance for start-up. On the original aircraft this was the bomb-release button. *(P. Blackah/Crown Copyright)*

3 The engine start isolation switch is set to 'on'. *(P. Blackah/Crown Copyright)*

4 The fuel priming plunger locknut is unscrewed... *(P. Blackah/Crown Copyright)*

5 ...and the Ki Gas primer is operated. *(P. Blackah/Crown Copyright)*

6 The propeller pitch control is set to fully forward (fully fine pitch). *(P. Blackah/Crown Copyright)*

7 The magneto switches are moved up to the 'on' position. *(P. Blackah/Crown Copyright)*

8 The fuel selector is set to 'on'. *(P. Blackah/Crown Copyright)*

9 The engine start button and booster coil buttons are pressed simultaneously. As the engine starts to turn, the priming pump is worked vigorously. If the engine does not start within 20 seconds the start and booster coil buttons are released for 30 seconds before attempting a restart. *(P. Blackah/Crown Copyright)*

10 Belching smoke from the exhausts, the engine bursts into life. The starter button is released, and when the engine is running satisfactorily the booster coil button is released and the priming pump plunger locknut is tightened. *(P. Blackah/Crown Copyright)*

Pre-take-off checks

The following checks must always be performed prior to take-off:

Trims	Elevator set ½ division up from 3 o'clock Rudder fully **right**
Throttle friction	Tight
Mixture control	Fully back
Propeller pitch control	Fully forward
Pressure head heater	As required
Fuel	Fuel cock – ON Low pressure warning light – OUT Priming pump – Screwed fully down Contents – Sufficient
Flaps	UP, mechanical indicators flush
Radiator flaps(s)	Open
Gyros	DI (Direction Indicator) synchronised, uncaged, artificial horizon erect
Hood	As required
Harness	Tight and locked

Landing

The following checks must always be performed prior to landing:

Field approach checks	
Fuel	Check contents
QFE	(Altimeter setting to indicate height above landing field) Set
DI	(Direction Indicator) Synchronised with compass
Radiator flap(s)	Open
Harness	Tight and locked
ROM	2,650rpm
Pre-landing checks	
Pneumatic pressure	Sufficient
Landing gear	Down (below 120 knots (NO)/140 knots (NE)) Indicates DOWN (green) Hydraulic indicator IDLE Lever in gate
Propeller pitch control	Fully forward
Flaps	Down (below 120 knots) Mechanical indicators up
Hood	As required
Checks on final approach	
Landing gear	DOWN (green) IDLE
Pneumatic pressure	Checked
After landing checks	
Pressure head heater	OFF
Flaps	UP, indicators flush
Radiator flap(s)	Check open
Pneumatic and brake pressures	120psi minimum
Throttle friction	Adjusted

ABOVE: Alex Henshaw was the chief production test pilot at the Castle Bromwich factory, during the course of which he test-flew more than one in ten of all the Spitfires built. He is pictured with Prime Minister Winston Churchill when the latter paid a morale boosting visit to the plant. *(Vickers)*

BELOW AND OPPOSITE: Spitfire Mark V, pictured soon after its introduction into service in 1941. This aircraft belonged to No 92 Squadron and was flown by Flying Officer Alan Wright. *(RAF Museum/Charles Brown)*

Wartime pilots' views

Production test pilot – Alex Henshaw

Alex Henshaw was chief test pilot at the huge Castle Bromwich plant, responsible for testing Spitfires as they came off the production line. While in that post he personally test-flew 2,360 Spitfires and Seafires – more than one in ten of all of those built. In this section he describes what the task entailed:

'As a production test pilot, one's task is really that of flight inspector; one has to satisfy oneself that everything works as it should and that the aircraft behaves as it was designed to. Unless there was some unforeseen snag, the flight test procedure for the Spitfire was straightforward. The procedure differed somewhat from mark to mark, so in this description I shall confine myself to that for the Mark V.

'After a thorough pre-flight check I would take off and, once at circuit height, I would trim the aircraft and try to get her to fly straight-and-level with hands off the stick. The Mark V lacked aileron trim tabs and most of the new ones had a tendency to fly with one wing low. When that happened I would land immediately and taxi to one corner of the airfield, where a mechanic would be waiting. He carried a special tool rather like a tuning fork, and on my instruction he would bend the trailing edge of the aileron on his side once, twice or thrice, up or down. Then he would go round to the other side, and similarly bend the opposite aileron in the other direction. That done I would take off again and trim the aircraft to fly hands-off, to see whether the wing dropping had been cleared; usually it had, but if it had not the process was repeated until the trim was acceptable (sometimes, if bending alone was not sufficient, it was necessary to change the ailerons). It was a Heath Robinson system, but it did work.

'Once the trim was satisfactory, I would take the Spitfire up in a full throttle climb at 2,850rpm to the rated altitude of the supercharger blower. Then I would make a careful check of the power output from the engine, calibrated for height and temperature. Many factors could give a false reading: a leaking boost gauge line, a high ambient temperature, faulty calibration of the rev-counter, or even an incorrectly set-up

altimeter. If all appeared satisfactory, I would then put her into a dive at full power and 3,000rpm, and trim her to fly hands and feet off at 460mph [indicated air speed]. Unless this was all right, adjustments would be necessary to the elevator trim; or slight dressing down might be needed to the trailing edge of the tailplane.

'Personally, I never cleared a Spitfire unless I had carried out a few acrobatic tests to determine how good or how bad she was; but the extent of this depended upon how tired or how rushed we were. The production test was usually quite a brisk affair: the initial circuit lasted less than ten minutes and the main flight took between 20 and 30 minutes. Then the aircraft received a final once-over by our ground mechanics, any faults were rectified, and the Spitfire was ready for collection. Sometimes I would make more than 20 such test flights in a single day, necessary if previous bad weather had stopped flying and, with the production line going at full blast, the number of aircraft awaiting testing began to mount.

'I loved the Spitfire, in all of its many versions. But I have to admit that the later Marks, although they were faster than the earlier ones, were also much heavier and so did not handle so well. You did not have such positive control over them. One test of manoeuvrability was to throw the Spitfire into a flick roll and see how many times she rolled. With the Mark II or the Mark V one got two and a half flick rolls, but the Mark IX was heavier and you got only one and a half. With the later and still heavier versions one got even less. The essence of aircraft design is compromise, and an improvement at one end of the performance envelope is rarely achieved without deterioration somewhere else.'

BELOW: Squadron Leader Don MacDonell, commander of No 64 Squadron during the Battle of Britain. *(MacDonell)*

'Scramble!' – Squadron Leader Donald MacDonell

In Fighter Command the codeword 'Scramble' meant 'Get airborne as rapidly as possible'. When pilots received the order they ran to their aircraft as if their lives depended on it – because they did. Each 30-second delay in getting airborne meant around 1,000ft in altitude they would not have when they met the enemy. They knew that a Spitfire caught in the climb was easy meat for a Messerschmitt 109 attacking in a dive. Squadron Leader Donald MacDonell, commander of No 64 Squadron during the Battle of Britain, described the procedure for getting airborne:

'The orderly answering the telephone would shout "SCRAMBLE!" at the top of his voice and each pilot would dash for his aircraft. By the time one got there one mechanic would already have started the engine; the other would be holding the parachute up and help me strap it on. Once that was done I would clamber into the cockpit. He would pass my seat straps over my shoulders and help me fasten them. When I gave the thumbs-up he would shut the side door and I would pull tight the various straps. Next I would pull on my helmet, plug in the R/T lead and check that the engine was running

properly. If all was well I would wave to the ground crew to pull away the chocks. Then I would open the throttle and move forward out of my blast pen and across the grass to the take-off position. Once there I would line up, open the throttle wide and begin my take-off run with the rest of my pilots following as fast as they could. The whole thing, from the scramble order to the last aircraft leaving the ground, took about a minute and a half.

'As soon as Spitfires were all off the ground and climbing, I would inform operations. The Sector Controller would come back and tell me where he wanted me to go and at what altitude. While the squadron was forming up I would climb in a wide spiral at low boost, until everyone was in place. Then I would open up to a high throttle setting to get to altitude as fast as possible.'

Shaken, but not stirred! – Pilot Officer Eric Marrs

Pilot Officer Eric Marrs flew Spitfires with No 152 Squadron during the Battle of Britain. In a letter to his parents he described the action on 30 September 1940, when his fighter brought him home safely despite severe battle damage.

'We were just going in to attack when somebody yelled "Messerschmitts!" over the R.T. and the whole squadron split up. Actually it was a false alarm. Anyway, being on my own I debated what to do. The bombers were my object, so I snooped in under the 110s and attacked the bombers (about 40–50 Heinkel 111s) from the starboard beam.

'I got in a burst of about three seconds when – Crash! and the whole world seemed to be tumbling in on me. I pushed the stick forward hard, went into a vertical dive and held it until I was below cloud. I had a look round. The chief trouble was that petrol was gushing into the cockpit at the rate of gallons all over my feet, and there was a sort of lake of petrol in the bottom of the cockpit. My knee and leg were tingling all over as if I had pushed them into a bed of nettles. There was a bullet hole in my windscreen where a bullet had come in and entered the dashboard, knocking away the starter button. Another bullet, I think an explosive one, had knocked away one of my petrol taps in front of the joystick, spattering my leg with little splinters and sending a chunk of something through the back of my petrol tank near the bottom. I had obviously run into some pretty good crossfire from the Heinkels.

'I made for home at top speed to get there before all my petrol ran out. I was about 15 miles from the aerodrome and it was a heart-rending business with all that petrol gushing over my legs and the constant danger of fire. About five miles from the 'drome smoke began to come from under my dashboard. I thought the whole thing might blow up at any minute, so I switched off my engine. The smoke stopped. I glided towards the 'drome and tried putting my wheels down. One came down and the other remained stuck up. I tried to get the one that was down up again. It was stuck down. There was nothing for it but to make a one-wheel landing. I switched on my engine again to make the aerodrome. It took me some way and then began to smoke again, so I hastily switched off. I was now near enough and made a normal approach and held off. I made a good landing, touching down lightly. The unsupported wing slowly began to drop. I was able to hold it up for some time and then down came the wing tip on the ground. I began to slew round and counteracted as much as possible with the brake on the wheel which was down. I ended up going sideways on one wheel, a tail wheel and a wing tip. Luckily, the good tyre held out and the only damage to the aeroplane, apart from that done by the bullets, is a wing tip that is easily replaceable.

'I hopped out and went off to the M.O. to get a lot of metal splinters picked out of my leg and wrist. I felt jolly glad to be down on the ground without having caught fire.'

A reconnaissance pilot remembers – Pilot Officer Gordon Green

Pilot Officer Gordon Green flew Spitfires with the Photographic Reconnaissance Unit (PRU) early in the war. In this account he gives his impressions of this task:

'Looking back at my time with the PRU, I get a lot of satisfaction from the knowledge that although I played my part in the war I never had to fire a shot in anger. In one sense we in the reconnaissance business had things easy. All

ABOVE: In its element: a reconnaissance Spitfire XIX at high altitude, during handling tests when fitted with a 170-gallon ferry tank under the fuselage. *(Crown Copyright)*

the time it was impressed on us: bring back the photographs and, if you can't, bring back the aeroplane. An infantryman taking part in the advance at Alamein could not suddenly decide "This is ridiculous, I'm going home!" He just had to go on. But if we thought we had lost the element of surprise we were not only permitted to turn back, we were expected to do so.

'On the other hand there were times when I knew real fear. When one was 15 minutes out from Brest on a low altitude sortie, one's heart was beating away and as the target got nearer one's mouth got completely dry. Anyone who was not frightened at the thought of going in to photograph one of the most heavily defended targets in Europe, was not human. Whenever it was possible to photograph a target, flak could engage us: if we could see to photograph [the ground] they could see to open up at us. But throughout my time as a reconnaissance pilot my luck held. I never once saw an enemy fighter, nor was my aircraft ever hit by flak. Indeed only once during the time we were flying those missions over Brest did one of our aircraft come back with any damage, and that was only minor. It was all rather like a fox hunt – either the fox got away unscathed or else it was caught and killed. There was rarely anything in between.'

A German pilot remembers – *Oberleutnant* Hans Schmoller-Haldy

Oberleutnant Hans Schmoller-Haldy flew Messerschmitt 109Es during the Battle of Britain. Later he had the opportunity to fly a captured Spitfire. These were his impressions:

'My first impression was that it had a beautiful engine. It purred. The engine of the Messerschmitt 109 was very loud. Also the Spitfire was easier to fly, and to land. The 109 was unforgiving of any inattention. I felt familiar with the Spitfire from the very start. That was my first and lasting impression. But with my experience of the 109, I personally would not have traded it for a Spitfire. I had the impression, though I did not fly the Spitfire long enough to prove it, that the 109 was the faster, especially in the dive. Also, I think the pilot's view was better from the 109. In the Spitfire one flew further back, sat more over the wing.

'For fighter-versus-fighter combat, I thought the Spitfire was better armed than the 109. The [20mm Oerlikon] cannon fitted to the 109 were not much use against enemy fighters, and the machine guns on top of the engine often suffered stoppages. The cannon were good if they scored a hit, but their rate of fire was very low. The cannon had greater range than the machine guns. But we were always told that in a dogfight one could not hope to hit anything at ranges greater than 50 metres, it was necessary to close in to short range.'

BELOW: Captured Spitfire I pictured at the Luftwaffe test centre at Rechlin near Berlin.
(Alfred Price Collection)

OPPOSITE TOP: Built at Castle Bromwich in 1944, Mark IX ML417 was delivered to No 443 (RCAF) Squadron on 2 June and it saw action over France on D-Day. It was credited with two Bf 109s destroyed and one damaged, and an Fw 190 damaged. The aircraft currently belongs to Tom Friedkin and flies from Chino, California. *(Neil Bridges)*

OPPOSITE BOTTOM: Spitfire Mark 22 being put through its paces for photographer Charles Brown, clearly showing the locations of the radiators under the wings. *(RAF Museum/Charles Brown)*

Display flying a Spitfire

Did you hear the one about the entrepreneur who found a way to make a million pounds out of hiring Spitfires for air displays? He started with £3 million and knew when to stop...

Within the flying community, air show organisers are notorious for paying the bare minimum they can get away with. They certainly do not, and probably cannot, pay the true cost of flying the display aircraft. The rate of payment usually depends on the distance of the air show from the aircraft's home base, and the duration of its display. For a privately-owned Spitfire to display at a venue within 60 miles of base, a typical figure is £2,500. That just about covers the cost of fuel and the maintenance, leaving no contribution towards the insurance. The true hourly cost of operating a Spitfire, if one took all of the factors into account, is of the order of £5,000.

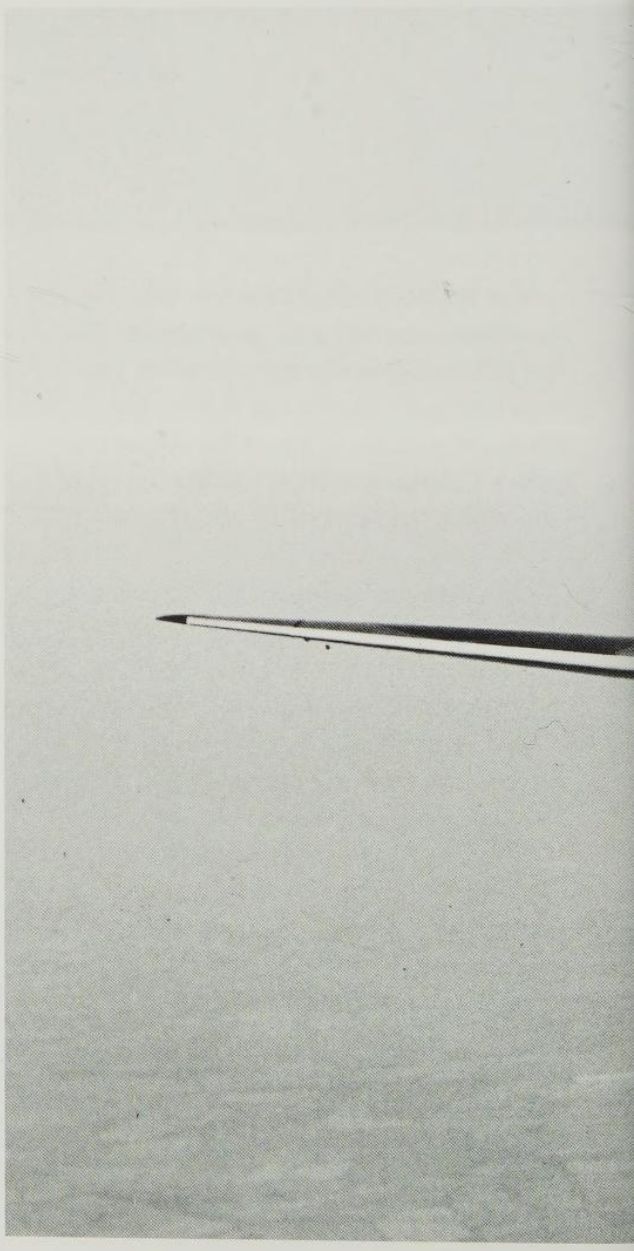
Another problem with air shows is that there are not enough of them. On any given Saturday or Sunday during the 2007 display season in the United Kingdom, there are probably about 20 Spitfires available to fly. But there are not 20 air shows every week. Hiring out aircraft for TV or film work pays much better money, but there is not enough of that work either.

Design defect

If the Spitfire can be said to have a design defect, it is that the underwing radiators sit immediately behind the undercarriage legs, and also outside the slipstream from the propeller. On a hot day, seven minutes is about the maximum a Spitfire can spend taxiing on the ground. Any longer than that and there is a serious risk that the liquid coolant will boil. If the engine is run at high power after that, it is liable to suffer damage. The problem is less severe with aircraft like the Mustang and the Hurricane, which have their radiators in line with the propeller and so get a constant flow of air pushed into the entry duct.

After take-off on a hot day, many Spitfire display pilots will move to a holding area clear of the airfield. There they will spend a few minutes flying at cruise power, typically 2,000rpm and plus 1lb boost, to allow the engine time to cool down before they commence their display.

On the landing approach on a hot day, a Spitfire pilot faces a similar problem. When the pilot lowers the wheels, the undercarriage legs are in front of the radiators and they block off part of the airflow going through them. Once the landing gear is lowered, the pilot can watch the engine coolant temperature rise steadily. That condition is further exacerbated when the flaps are lowered, because these are located behind the radiators and cause further interference with the airflow passing through them. Because of this, once in the landing pattern an experienced Spitfire pilot will lower the flaps as late as possible to avoid the engine overheating when taxiing on the ground.



ML417

ABOVE: Spitfire XVI TD248, often flown by Cliff Spink during displays. *(Neil Bridges)*

Cliff Spink, air display pilot

Cliff describes the standard display he gives with the Spitfire. He often flies the privately owned Mark XVI TD248:

'When planning a display, one of the primary concerns is preserving the longevity of the aircraft. You don't need to fly the Spitfire close to its limits to give a good display. The engine is the most critical item in the aeroplane and engine management is an important part of the display. We hope to get 500 flying hours out of an engine. Bear in mind that these aircraft fly between 25 and 50 hours per year, so we hope to get ten years of flying out of a Merlin.

'We work to husband the resource. Because we operate the plane light, at low level, we run the engine at about one-half its maximum rated power. Flat out you could push the Merlin up to plus 12lb boost, but that would cane the engine and cause unnecessary wear. In displays I tend to set the engine at its maximum continuous power setting, at plus 6lb boost, so it's grossly under-run.

'The Spitfire has a lovely big wing and you can operate it in a wide regime of speeds, both slow and fast. I can do a display in the Spitfire and never exceed 4G. And, of course, one does not hold that 4G for long. If you enter a vertical manoeuvre, while you might pull 4G in the first few degrees, as the speed comes off the G forces drop rapidly. During a display the fastest speed I reach is about 270 knots [311mph].

'There are core manoeuvres I use when showing off the Spitfire in the air: loops, barrel rolls, aileron rolls. When going through a horizontal eight manoeuvre I might go to zero G, but I avoid applying negative G. The engine was not designed to run for any length of time at negative G, and in any case it would not improve the display in any way to do so.

'The people who fly these aeroplanes are, by definition, enthusiasts. They certainly don't do it for the money, because the pilots don't get any. We enjoy flying the aeroplanes because they're so thrilling to fly. At the same time it is a great privilege to be allowed to do so.

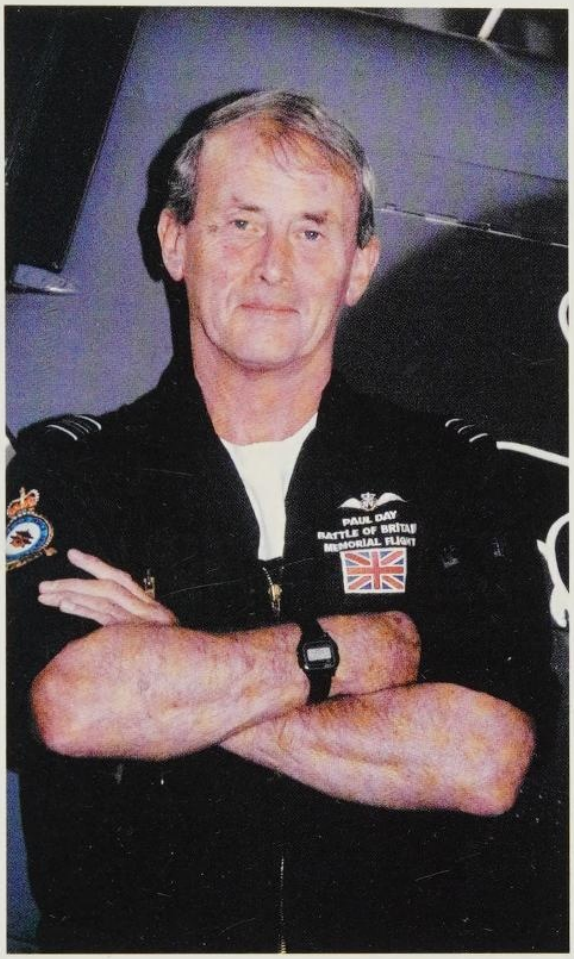
'There's great camaraderie between the Warbird pilots. I enjoy their company, they're good fun. They've shown themselves to have

a level of skill and attitude that's appropriate to flying these old aeroplanes. I like to think we'll leave behind a vibrant body of supporters who'll ensure that these aircraft will continue to fly in the decades to come. It's not a closed shop. We're constantly looking for suitable people – and there are a lot of them out there – trying to make their way into this world. It's just as important to maintain the flow of pilots as it is to keep the aeroplanes going. It's no good having a bunch of elderly pilots, all about to drop off their perch at the same time, leaving nobody to replace them.'

Paul Day, Spitfire display pilot

Paul Day commanded the Battle of Britain Memorial Flight from 1996 until he retired from the service in 2004. Since leaving the service he flies the Mark IX Spitfire MJ627, a two-seater owned by Maurice Bayliss. In this account he describes the thinking behind the BBMF during his time in command of the Flight:

'Generally speaking, a volunteer pilot did only two or three seasons with the Flight. In



LEFT: Squadron Leader Paul Day ('The Major') joined the BBMF in 1980 as a volunteer pilot. In 1996 he was appointed commander of the unit, and held that post until he retired from the service in 2004. *(Crown Copyright)*

BELOW: Since leaving the RAF Paul Day has continued to fly Spitfires, in this case Maurice Bayliss's two-seater Mark IX trainer MJ627. *(Andrea Featherby)*

that time he wasn't going to reach a fantastically high aerobatic standard. Consequently, we designed a display that was extremely simple, and semi-aerobatic flying rather than fully aerobatic. The aim was to present the aeroplane rather than the brilliance of the pilot. That's what most people had come to see.

'In my years with the BBMF we kept essentially to the same display routine. Some people might say that was boring, but the majority said they loved the way we handle the aeroplanes, we knew how to look after them. We put them in front of the public in a way they fully appreciated, and with no risk.

'The best way to do this, and not have accidents, is to use highly qualified people, doing a very simple display, which they can repeat all the time virtually regardless of the weather, in aeroplanes maintained by the most highly qualified technicians you can get. That's a hard act to beat.

'The normal operating G pulled was plus 3G, never exceeding plus 4G, with no negative or reduced G. The maximum airspeed limit was 270 knots [311mph]. The maximum crosswind limit allowed was between 10 and 15 knots [depending on the Spitfire variant and the experience of the pilot]. There was no flying in rain, because rain can damage the wooden propeller blades. We didn't do loops, only wingover manoeuvres and rolls.

'The display was put together to ensure that the pilot doesn't get into a situation from which it might become difficult to recover. No display is worth putting an aircraft at risk. Good pilots avoid trouble, they don't rely on being able to fly their way out of it.'

The BBMF display

The Warbird aircraft are stripped of armament and much of their military equipment. As a result they operate in a much lighter mode, of the order of 25 per cent less, than a World War Two Spitfire in operational state. That makes these aircraft much livelier than they were originally.

Al Pinner, present commander of the Flight, describes the thinking behind the unit's displays. As always, the primary aim is to present the aeroplane in an exciting yet safe manner:

'The thing I stress to pilots when they join the Flight is that there is absolutely no room for ego when flying these aircraft. The people in the crowd couldn't care less who the driver is. They've come to see the beautiful sight of these aircraft, and to hear the evocative note from their engines. We keep the displays standardised and simple, so we don't have to use an excessive number of our precious flying hours in training.'

Al now takes us through his solo display in the Spitfire. Although to the spectators it will seem longer, the standard display takes only about 4½ minutes from the initial run in to

the victory roll at the end. Readers may find it useful to use their hands when following his description:

'The initial run in is from the crowd's left. It takes one to a point in front of the centre of the crowd at an altitude of 100ft, then into a left-hand level break. That takes the aircraft away from the crowd on a 30° line, running out for a few seconds. The pilot then pulls into a Derry wing-over, a pitch up to about 30° nose-up followed by a roll to the left going all the way underneath. The aircraft comes out banking to the right, to come back on the crowd line for a high-speed pass from the crowd's right to the crowd's left.

'A few seconds after passing the crowd centre line, pull up into another Derry wing-over to the left, turning to the right. That puts the aircraft running back towards crowd central at 45° from the crowd's left. Then do a left-hand break into a 360° turn. From there, roll out on the 30° line heading away from the crowd, extending a little bit, then pull up into a wing-over to the right.

'Going from crowd right to crowd left, go through the centre line into what we call a

BELOW: The BBMF's Mark IX, MK356, gets airborne prior to beginning another display. *(Crown Copyright)*

horseshoe: a 90° break pointing away from the crowd. Hold that for about five seconds, then pitch up for a right-hand wing-over to bring the aircraft back towards the crowd. Next comes another right-hand break, to head away from the crowd's left on the 45° line. Pitch up into a wing-over to the left, running along the crowd line from crowd left to crowd right. Then pull up into a victory roll, aiming to be inverted when passing over the crowd centre, before exiting stage right. And that's the display completed, in about 4½ minutes.'

A boyhood dream fulfilled

Like many before him and since, Clive Denney dreamt of flying a Spitfire when he was a small boy, and after working hard to obtain his Private Pilot's Licence, and his involvement in restoring Spitfire Mk XVI RW382, he made his dream come true. Today, Clive and his wife Linda run Vintage Fabrics Ltd, specialising in aircraft fabric recovering and aircraft paint schemes. The authors are grateful to Clive Denney for permission to use this account.

Clive Denney – Spitfire pilot and restoration expert

Ask anybody to name two aeroplane types, and the chances are that one of them will be the Concorde and the other will be the Spitfire. Ask pilots at any level which aeroplane they would give anything to fly, and most will answer "the Spitfire".

So what is it that makes this little fighter of a bygone age so popular? For me it started as a child with my two-shilling (10p) Airfix kit in its clear plastic bag, its beautiful lines just waiting to be built, painted and flown around my back garden. Swooping, diving, held between my two fingers, it was easy to fly.

Thirty years later I was about to find out for real. Having been involved in the restoration of a Spitfire Mark XVI RW382 and having passed the test, so to speak, here I was at Duxford on a bright July day. There was the Spitfire, myself, my PPL [private pilot's licence] with a grand total of 275 flying hours logged.

How did I feel? The excitement was beyond belief. But having been around this Spitfire for the past three years I felt I knew her well, and she would look after me.

After completing a good walk-round check, it's time to climb aboard. The first impression of the cockpit is how comfortable it is, small yet a snug fit with all the controls easy to access and handle. There is the standard British blind flying panel, so familiar on most British vintage types. It takes very little time to feel totally at home.

Now to get the mighty Merlin started. Brakes on, fuel on, idle-cut-off to off, pre-oiler on for two minutes, fuel pump on for ten seconds to prime the lines, Ki gas pump open and prime the engine with six strokes. We are now ready to start: idle-cut-off to run, the propeller in fully fine [pitch], throttle set, booster coil and starter buttons exposed. A check round outside followed by a loud shout of "Clear prop!" The booster coil and start buttons are pressed together and the huge prop begins to turn. Magnetos on. The smell of the exhaust, the sound of the pure music produced by the 12 cylinders, can only be appreciated from inside the cockpit. With temps [temperatures] and pressures all OK, it is time to taxi.

"Duxford, Spitfire G-XVIA, request radio check and taxi." I can't believe that I said that, my dream is about to come true. Duxford: "Spitfire clear to taxi, runway 06 left hand, QFE 1016 QNH 1018" [barometric pressure at the airfield 1016 millibars, standard pressure at sea level 1018 millibars]. "Spitfire, Roger."

Close the throttle, wave the chocks away. Brakes off and gently move forward, a quick check of the brakes and then taxi to the holding point ready to take off. The taxi out is really a delight; although a long nose hides forward vision. The standard tail-wheel taxi method of weaving from side to side makes it easy; in Tiger Moths and Chipmunks the method is the same.

At the hold it's time for the engine checks prior to take-off. Once pointing into wind the brakes are applied and there is a quick check of temps and pressures. All OK, so the power is taken up to 1,800rpm. With the stick held hard back the noise level rises greatly. Temps are rising now so there is no time to hang around. Check magnetos 1 and 2 [switch off first one then the other, maximum drop permitted is

50rpm]. All OK. Check the prop twice [in fine pitch], test the supercharger. With the coolant temps still within limits, check the slow running.

Things happen quickly now, pre-take-off checks are in the head not on a list: automatic trim set, elevator two divisions up, right rudder pedal pushed fully forward, throttle locked, (most important) fuel on, canopy locked, harness tight and check controls for full and free movement.

"Spitfire ready for departure," temps around 95°. "Spitfire clear take-off, wind 070 10 knots." This is it, no going back!

I open the throttle gently and the noise level goes through the roof. The control column is hard over to the right, with full right rudder. To my surprise she runs as straight as a die. More power is now applied, with plus 6lb of boost the tail is raised. She flies off with ease. Now comes the part that every new Spitfire pilot dreads – getting the gear up. For that you have to change hands on the stick, but again to my surprise it is not a problem. The gear hits the locks and the red light comes on; up. This all happens very quickly. Where the hell are we? She climbs like a homesick angel. I pull the power back to plus 4 boost and 2,400rpm and climb away at around 140mph. Now I realise just what an absolute thoroughbred this aeroplane is.

The ailerons are fairly heavy but extremely responsive, the elevators are so light in pitch. We are now cleaned up, the radiator flaps are in automatic and the engine is set to 0 boost 2,000rpm. Let's just float around for a while and get the feel. The view from the tiny cockpit is very good, no doubt helped by the fact this Spitfire has a bubble canopy. It is hard to realise that this beautiful aeroplane was a purpose-built killing machine. It felt as if the years were rolling back to 1940 but this was 1991, and my first flight, and there was still lots to do and learn.

I carried out some stalls, some clean and some dirty [with the landing gear and the flaps down]. No real surprise there. It is just as described in the brief, with a slight buffeting and a small amount of wing drop, but all perfectly normal in recovery. Then I fly a practice circuit at height, using a main road for runway reference. I run in down wind with the gear down, all below 160mph. At the end of the downwind leg I drop the flaps, boy how the nose bobs, then trim and bring the speed back to 110mph. I overshoot and go round, raising the gear. This is all at around at 2,000ft. Having felt comfortable with the circuit at height, there is time to fly around for five minutes before tackling the landing. I can't stay airborne for ever.

"Duxford, Spitfire to the north looking to rejoin." "Spitfire clear, run and break runway 06 RH." I breeze over Duxford at about 800ft, turn right at the end of runway 06 and get the speed back below 160 to drop the gear and join downwind for landing. The downwind checks carried out, I call finals, trim again, speed back to 85mph. She really feels like she's on rails, rock steady. Flying a curved approach throughout, the runway disappears under the wing; 80mph over the [runway] numbers, then flare and chop the power. She settles down with a little skip and hop, but still runs straight as a die. A little brake is applied, but given the length of the grass runway I decide to let her run out of speed. She comes to a halt and I turn left to clear the runway.

All my colleagues, family and friends are waiting in front of the tower. I turn into wind, the coolant temp's around l00° so I can't hang about (115° is the maximum temperature allowed). Then I carry out the shut-down checks. After checking the magnetos again I switch off the radio, set the idle-cut-off to off. There is a slight rise in rpm, then the engine dies. Silence. Magnetos off, fuel off, brakes off, battery off, giro caged. Now all I hear is the gentle ticking from the hot exhausts as they start to cool. The warm smell in the cockpit is like the finest perfume.

All around people are talking to me, but I'm oblivious to what they are saying. I have just fulfilled a lifelong dream, and I want to savour every second of it. It's time to get out. Now it is time to debrief and clean the aircraft.

All of that was 16 years ago, and today it is still vivid in my mind. I've never lost my grin and I never will. I'm still flying Spitfires, and have flown five different Spitfires of varying marks: the Mark V, the Mark IX and the Mark XVI. I can say the Spitfire is the most remarkable aeroplane I will ever fly, she is every pilot's dream. Long may she remain so.

'Despite being 'only' ground crew, it is still such a privelege and a thrill to work with such an historic aircraft. The old engineering adage "If it looks right, it usually is right" is illustrated perfectly by the Spitfire, some 70 years after the prototype first flew.'

Paul Blackah,
Battle of Britain Memorial Flight, Airframe Specialist

(Photo: P. Blackah/Crown Copyright)

Chapter Five

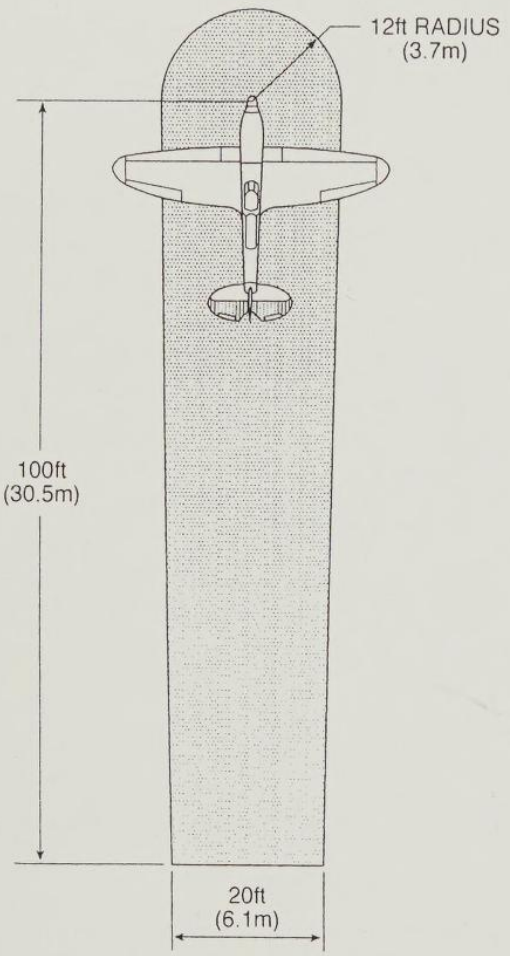
The engineer's view

Aircraft design and technology constantly evolves and the skills needed to maintain, service and fly our historic aircraft are slowly being lost. Only specialised units such as the BBMF, the Aircraft Restoration Company, the Historic Aircraft Company and a select group of private owners acquire the specialised skills that were common over 60 years ago.

This chapter should enable the reader to gain further insight into the restoration, daily care and maintenance of a Spitfire.

71/00 Engine Danger Areas

Do not go into the areas shown in Fig 1 if the engine is in operation unless you are specifically detailed to do so.



ABOVE: An illustration showing the danger zone created by the propeller and its wash when the engine is running. *(Crown Copyright)*

RIGHT: A typical mobile tool chest at the BBMF. A system of tags is used so that each tool is signed out – this is to ensure that all tools can be accounted for and that none is left in an aircraft. *(Crown Copyright)*

Safety first!

Even when it is on the ground a Spitfire can kill you if not treated with due respect. It may appear obvious that a moving propeller can kill or injure you. However, a static propeller should always be treated as 'live'. Even with the ignition in the 'off' position, it may continue to rotate after being hand turned, especially when the engine is hot.

Care should be taken when operating the flying controls to ensure that there are no personnel or items of equipment in the immediate area. Being struck by an opening flap could ruin your entire day!

Ear defenders are essential when the engine is running, as prolonged exposure to engine noise can cause partial deafness. Correct clothing should be worn at all times – no loose belts, ties or jewellery, as these may be caught in the machinery and cause injury or loss of limbs.

When replenishing the oil supplies, care must be taken to ensure that the container does actually contain the oil that you require. There are so many lubricants and fluids that are packaged in similar-sized and coloured tins that mistakes can happen.

Finally, whilst entering a cockpit, pockets should be empty to prevent Foreign Object Damage (FOD) occurring. Something as small as a coin could jam the controls, with possible fatal consequences if it happened in the air.

Tools and working facilities

For day-to-day management of the Spitfire a good selection of BA, BSF and Whitworth spanners and sockets is essential. Pneumatic tools such as drills and riveting hammers are favoured, as are wire-locking pliers, files and the other more common tools within a standard kit.

The more specialised jobs, such as stripping down hydraulic components or an engine, require specific tools that will be specified in the relevant overhaul manuals. Some are difficult to obtain due to rarity and in some cases may have to be manufactured to order.

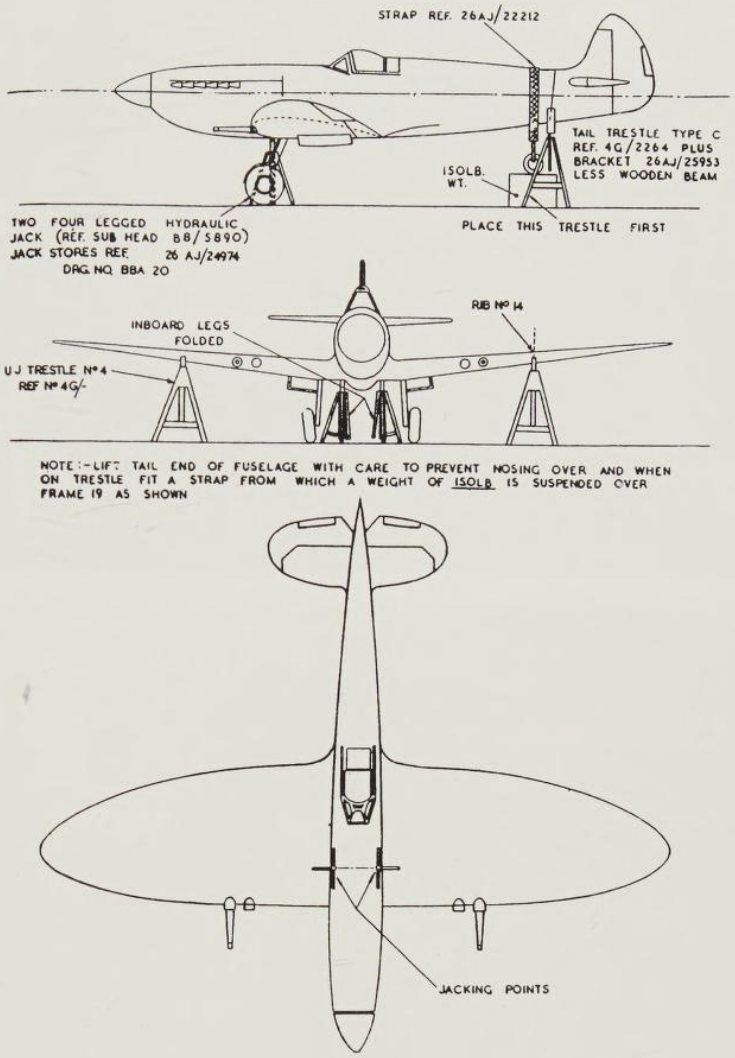
Jacking and airframe support

Jacking and trestling

When jacking a Spitfire, the first stage involves lifting the tail onto a tail trestle and strapping ballast over the rear fuselage to stop the aircraft tipping forwards onto its propeller. Next, two five-tonne jacks are placed under the fuselage at Frame 5, where there are two cup-like brackets that the ball of the jack will slot into. The aircraft is then jacked sufficiently high off the ground to enable the undercarriage to be retracted. Finally, wing-steadying trestles are positioned under each wing.

Arc lifting

This method of support is used when changing a tyre or main wheel. Firstly the aircraft is chocked at the tail and at the main undercarriage wheel on the side that isn't being lifted. A jack is then put in place on the side to be jacked, and the aircraft is lifted high enough to allow the wheel to be removed. As this is a quick procedure wing trestles are not used.


STRAP REF. 26AJ/22212
TAIL TRESTLE TYPE C REF. 4G/2264 PLUS BRACKET 26AJ/25953 LESS WOODEN BEAM
ISOLB. WT.
TWO FOUR LEGGED HYDRAULIC JACK (REF. SUB HEAD BB/5890) JACK STORES REF. 26 AJ/24974 DRG. NO. BBA 20
PLACE THIS TRESTLE FIRST
RIB Nº 14
INBOARD LEGS FOLDED
U J TRESTLE Nº 4 REF Nº 4G/-
NOTE:-LIFT TAIL END OF FUSELAGE WITH CARE TO PREVENT NOSING OVER AND WHEN ON TRESTLE FIT A STRAP FROM WHICH A WEIGHT OF ISOLB. IS SUSPENDED OVER FRAME 19 AS SHOWN
JACKING POINTS

A diagram showing the jacking and support points for use with jacks and trestles. *(Crown Copyright)*

RIGHT: With the tail of MK356 raised, note the decidedly low-tech but effective system for holding down the tail: a couple of jerricans filled with water joined by a rope running over the rear fuselage. The jacking pads under the fuselage firewall are close to the aircraft's centre of gravity. Without the extra weight near the tail, if an item of equipment is removed from the rear there is a risk that the aircraft will tip on to its nose. *(Crown Copyright)*

ABOVE LEFT: Positioning jacks under the wing-root jacking points on fuselage Frame 5... *(P. Blackah/Crown Copyright)*

ABOVE: ...and raising the jacks to support the airframe. *(P. Blackah/Crown Copyright)*

LEFT: Jacking of MK356 completed. The undercarriage is now clear of the ground, and can be retracted if necessary. *(P. Blackah/Crown Copyright)*

BOTTOM: Once jacking is completed, steadying trestles are positioned under each wing. *(P. Blackah/Crown Copyright)*

Recommended lubricants and fluids

Fuel	Avgas 100LL/F18
Engine oil	OM270/W100
Hydraulic oil	OM15/H515
Coolant	AL3
Grease	XG287/G354 (Bearings)
Oil	OX14 (Hinge pins, chains etc)
Corrosion preventative	PX24
Gas charging undercarriage oleos and tyres	Nitrogen

Servicing a Spitfire

Regardless of whether a Spitfire belongs to the Battle of Britain Memorial Flight or is privately owned, much the same pattern of checks and servicing needs to be carried out at regular intervals in order to maintain the aircraft in an airworthy condition. This section lists the pattern of inspections for the Spitfire as used in the BBMF. Most civilian Spitfire owners follow that general pattern, though perhaps with minor changes to suit their individual circumstances.

On the BBMF, the major servicing cycle for a Spitfire is eight years. This cycle is worked out based on the hours flown, the components that are fitted, the aircraft's structure, known structural failures and the risks of flying a 60-year-old aircraft. All these factors are considered, and a schedule is produced. This schedule not only takes into consideration the aircraft itself, but also the parts within it that are given a specific lifespan, either in flying hours or by calendar time. For example, a magneto is lifed at 250 hours, so this would be removed, serviced or replaced, regardless of whether the aircraft itself was due a service. This also applies to calendared items such as the parachute, which is checked and re-packed every six months.

The Before Flight and Turnaround servicing procedures are usually carried out by a single technician. When the work is finished he or she signs the appropriate document, Form 705, in the Aircraft Flight Log, Form 700, to indicate that the aircraft has been checked and is ready for flight. The pilot signs on the same form to acknowledge that he accepts the aircraft as being ready for flight.

The Before Flight servicing procedures have to be carried out within 24 hours of the aircraft's scheduled take-off time. If for any reason the aircraft does not fly within that period, the servicing has to be repeated.

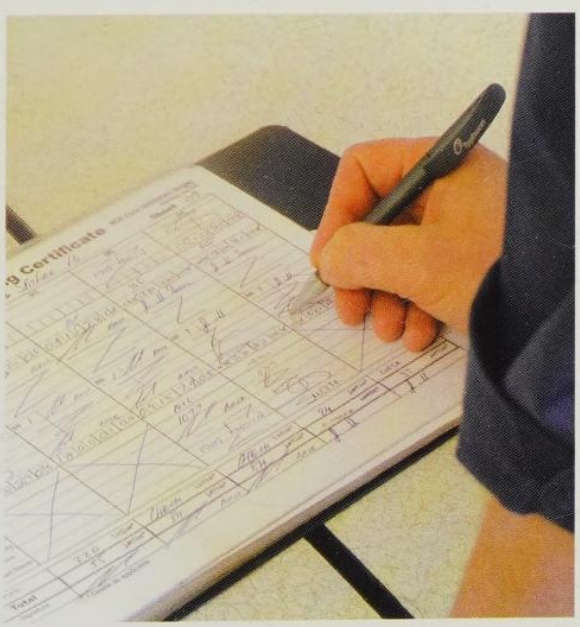
Before Flight Servicing

1. External check of aircraft and panels, to make sure all are secure.
2. Check the flying controls, to see they are in working order and move freely without restriction.
3. Check electrical systems, eg, navigation lights, pressure head (pitot) heater.
4. Ensure the oil, coolant, pneumatic and hydraulic systems have been replenished.
5. Check tyres for correct pressure.
6. Clean windscreen and canopy, if necessary.
7. Refuel aircraft with 100 LL (100 octane low lead) AVGas.
8. Visually check parachute, and tidy straps.

On return from the flight the pilot signs in the aircraft on Form 705, and reports any faults discovered to the technician in charge of servicing the aircraft. The pilot completes the relevant sections in Form 700. The technician then fills out a job card listing the faults requiring rectification. The types of problems that may be found after flying are things such as instrumentation failure, engine vibrations and trim problems.

BELOW LEFT: The technician in charge of servicing signs Form 705 to indicate that the aircraft has been checked and is ready for flight. *(P. Blackah/ Crown Copyright)*

BELOW: The details of Form 705. Once the technician has signed that the aircraft is ready for flight, the pilot must sign to confirm his acceptance. *(P. Blackah/Crown Copyright)*



Leaks

During a Before Flight, an After Flight or a Turnaround servicing, it is important to check the hardstanding beneath the aircraft for 'puddles'. Any leakage of liquid is potentially serious, and should be investigated immediately. Some small leakages are part and parcel of normal operation, however. For example, the engine might vent some oil when the lubrication system heats up. On a hot day it is not uncommon to find a small puddle of fuel under a Spitfire's wing. Once the system has been filled, the fuel might expand a little and the excess will vent. This sometimes occurs in the BBMF hangar, and it is not uncommon to have well-meaning visitors seek out technicians to pass on the important information that one of the aircraft is leaking.

An apparent lubricating fuel, oil, coolant or hydraulic fluid leak might be due to over-filling. By wiping away the excess, and waiting a short time to see whether the leak continues, the technician can assess whether the leak is serious. If the leak persists, the most usual cause is a loose pipe connection. If the source of the leak appears to be the engine, the latter is de-cowled and the pipe connections are examined to look for the leak. When it is found, tightening the pipe clamps will usually cure the problem. If a pipe develops a split, the relevant system has to be drained and the pipe replaced – if a replacement is available. Or, if no replacement is available, it may be necessary to manufacture one.

If the coolant leaks from one wing, the cause could be a loose pipe connection or a leaking radiator. If the latter, it will have to be removed for repair or replaced. Radiator repairs are carried out by a specialist company, and the task could take between two and four weeks depending on the company's workload at the time.

If a persistent leak of hydraulic fluid comes from the starboard engine panel, the hydraulic pump probably requires replacing. This is a four- to five-hour job. Alternatively, a leak of fluid beside one of the tyres will indicate that a seal on that undercarriage oleo leg requires replacing. The undercarriage leg is removed and the seals replaced, then the oil and air levels are restored. This would take about five hours.

If a fuel leak persists, it could be for one of a number of reasons. The leak usually shows up as blue staining on the aircraft skin, and a strong smell of petrol. If a leaking pipe is the cause it will need tightening or replacing, a relatively simple job.

The worst-case scenario for a fuel leak is when it occurs in the lower fuel tank. This requires the draining of the fuel system, then the removal of the upper fuel tank to gain access to the lower tank. There, the most likely cause of a leak will be from one of the bolt heads from the access panel. However, the lower tank has a rubber and fabric self-sealing covering. If there is a leak, fuel coming into contact with the layer of rubber on the outside of the tank sets up a chemical reaction which causes the rubber to swell until it seals off the leak. The reaction between the rubber and the fuel makes it more difficult to locate the leak, however, as the rubber soaks up the fuel like a sponge. If a leak is found, the tank has to be removed for repair and the entire self-sealing covering has to be replaced. This means sending the lower tank to a specialist company. On its return the lower tank is fitted, then the undercarriage has to have a retraction check to ensure that the hydraulic pipes in front of the lower fuel tank have sufficient clearance, and do not rip the self-sealing covering on the tank. Then the upper fuel tank is fitted and the pipes reconnected. The system is then filled with fuel and fingers are crossed, hoping that the tank has not been left dry for too long. Otherwise there could be a further leak and the whole process has to be repeated. A job that might take two days, best case, could take an aircraft out of use for a fortnight or longer, worst case.

Sometimes a leak will occur in flight, and reveal itself in a frightening manner. While giving a display at Southend, a BBMF Spitfire XIX began leaving what looked like a smoke trail. If that was the prelude to an engine fire, the pilot might need to take to his parachute. He moved into close formation on the BBMF Lancaster, which was carrying the ground crew. The latter observed that the trail was not smoke, but engine oil. That was a less immediate danger, but nevertheless the pilot was advised to land as soon as possible. On the landing approach the oil pressure gauge dropped to zero, but the pilot landed safely. An inspection found that an oil return pipe had come adrift, and the Griffon engine was out of oil. At the time the pilot shut down the engine, it was on the point of seizing up.

Still on the subject of leaks, there is one that does not announce its presence with a puddle or a trail: a leak in the Spitfire's pneumatic system. This system employs compressed air to operate the flaps and wheel brakes; a leak shows up on the pressure gauge on the instrument panel, and sluggish or non-operation of these services. To locate the leak the suspected area is sprayed with Snoop liquid, a mild detergent that is non-corrosive. When this liquid comes into contact with the stream of leaking air, the liquid froths up to show where the problem lies.

After Flight Servicing

1. Refuel.
2. Clean aircraft exterior, including windscreen and canopy, to maintain it in display condition. A detergent such as Ardrox is sprayed on the aircraft, and hand-wiped off.
3. Visually check parachute, and tidy straps.
4. Carry out a visual inspection to look for cracks and damage, eg, exhaust stubs that have holed, loose panel fasteners or screws, etc.

The After Flight servicing is carried out as soon as possible after landing. This ensures that any problems identified by the ground crew are corrected before the aircraft flies again. Problems that might be found by the ground crew after flying could be things such as worn tyres, broken fasteners and oil leaks.

Turnaround Servicing

(If aircraft is planned to fly again within a few hours of landing.)

1. Refuel if required.
2. Clean windscreen and canopy.
3. Very quick visual check.

Note: the oils and pressures are not checked at this point, as everything is too hot.

Primary Servicing

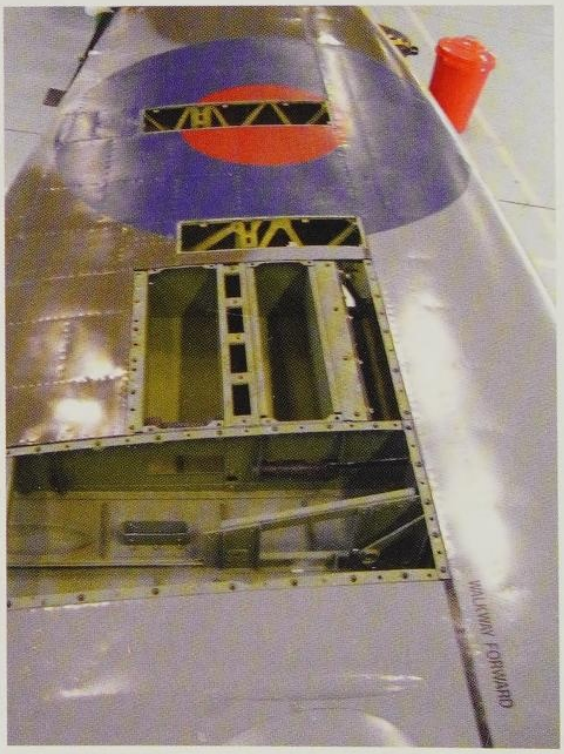
This servicing is carried out after 28 hours' flying time, or thereabouts. It consists of an inspection of the airframe and the engine to check for general wear and tear. This servicing is carried out by three technicians and takes approximately one day, provided there are no problems. Also:

1. The flying control hinge points, and the undercarriage system, are lubricated.
2. The propeller constant-speed unit filter, and the scavenge oil filter, are removed from the engine and checked for debris.
3. The oil is changed, and a soap sample is taken to check for any contaminants in the oil.
4. The magneto contact-breaker points are checked to ensure they are set correctly.

Annual Servicing

The Annual Servicing is carried out at 70 hours' flying time or one year, whichever the aircraft reaches first, and generally begins each September, at the end of the air display season. On a Spitfire it takes about five months, using three to four technicians. However, if more

BELOW: Corporal Kirkpatrick of the BBMF inspects an aileron mechanism on MK356 during annual servicing. *(P. Blackah/ Crown Copyright)*



ABOVE: MK356 is tied down for maximum power runs, before it goes into the hangar for partial dismantling and its annual servicing. Note that the chocks in front of the wheels are held in place by a rope attached to an anchor point under the tail, to prevent the aircraft pushing them forwards. The strop round the rear fuselage stops the tail lifting. *(P. Blackah/Crown Copyright)*

LEFT: Upper surface of the port wing of MK356 with access panels removed, showing the empty gun bays for the 20mm Hispano cannon, the two Browning .303in machine guns and their ammunition magazines. *(P. Blackah/Crown Copyright)*

OPPOSITE PAGE: MK356 on jacks with access panels removed from the lower surface of the starboard wing. *(P. Blackah/Crown Copyright)*

personnel can be concentrated on a single aircraft this time can be reduced in proportion. The inspection begins with ground-running the engine, to measure its performance. The aircraft then goes into the hangar, where it is raised on jacks and completely de-panelled to prepare it for the detailed inspection.

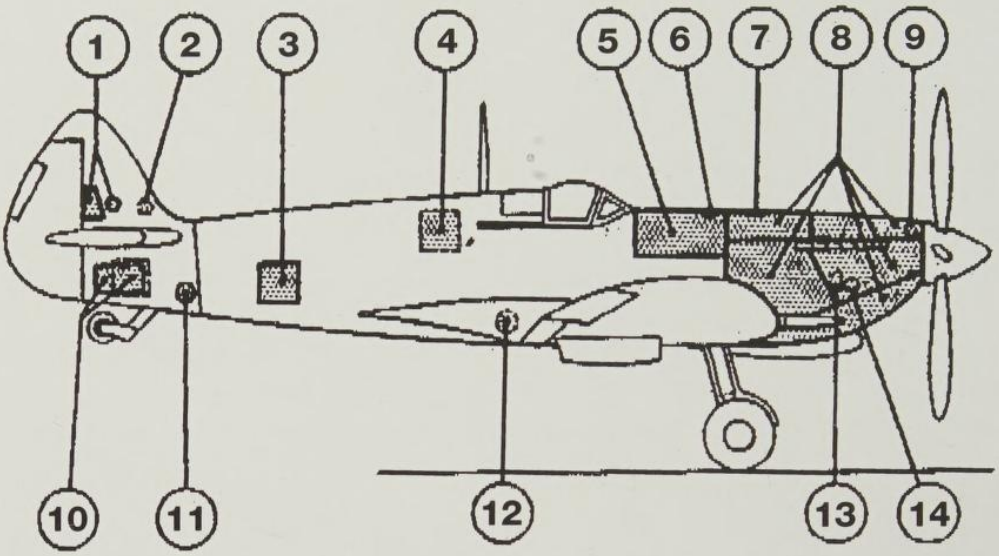
Although the majority of faults can be resolved using the resources at the BBMF, it can be time-consuming and frustrating if a part needs replacing and no spare is available. In such a case one of the specialist companies might be called in to produce a replacement part from an original drawing or by using an unusable part as a pattern.

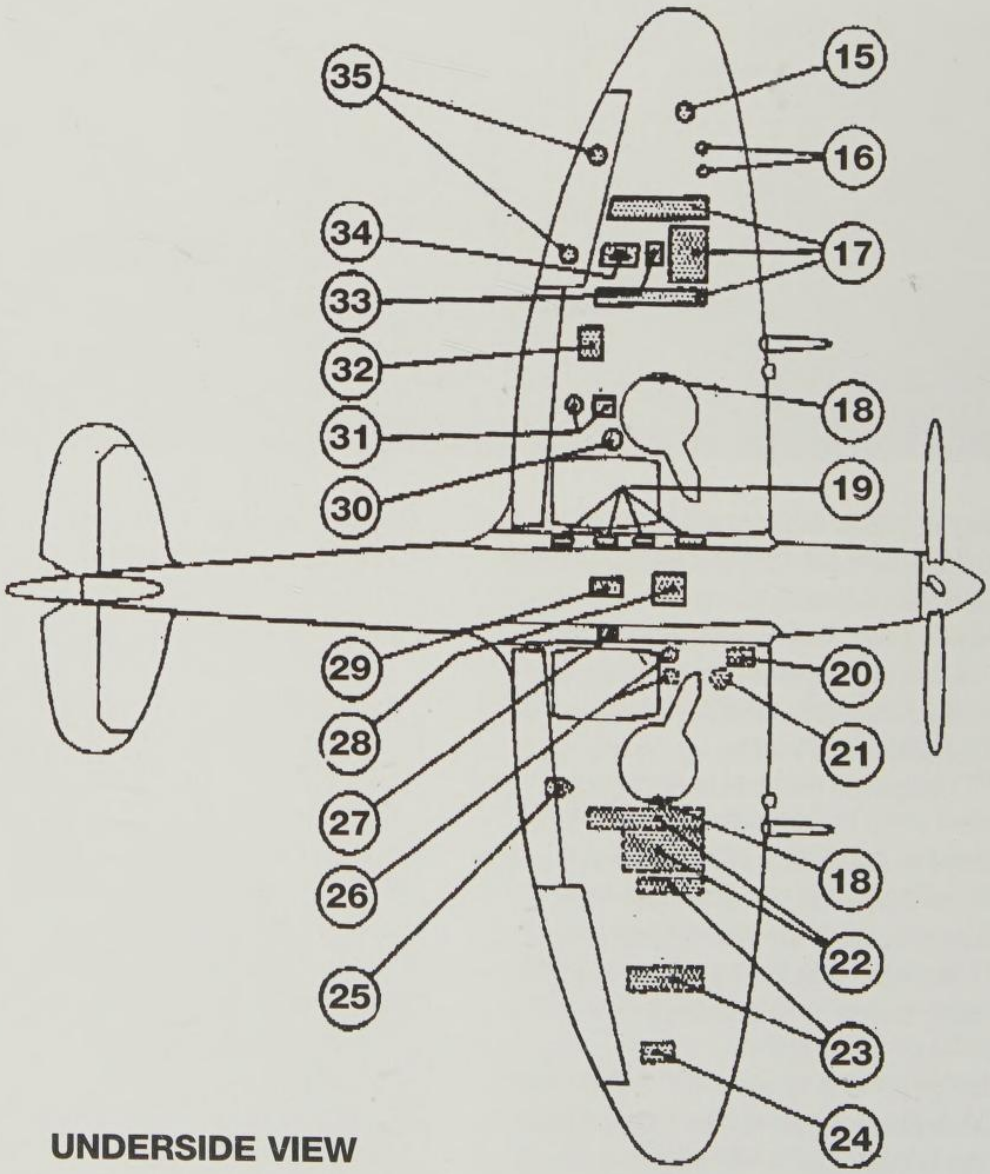
This servicing is carried out in greater depth, and includes all the procedures set out in the Primary Servicing schedule, plus:

1. The undercarriage legs are removed and the attaching pintles undergo non-destructive testing to look for possible cracking.
2. The oil in the undercarriage legs is replaced.
3. A detailed inspection is carried out looking for signs of possible cracks, corrosion and loose rivets.
4. The flying control cables are removed and examined for fraying and general wear and tear.
5. The engine rocker covers are removed, and the cams and followers are inspected for wear and tear. The propeller is inspected for wear and damage, as are the engine mounting frames and bolts.
6. The electrical wiring is inspected for wear and tear.
7. On refit, all of the above systems are tested. This includes an undercarriage retraction test, checking the flying controls for full range of movement, and ground-running the engine.

A diagram showing the locations of the various fuselage and wing access doors and inspection panels. *(Crown Copyright)*

1 Rudder trim screw jack and cables
2 Trim cable pulley
3 Rear fuselage access
4 Radio (now luggage stowage)
5 Main fuel tank cover
6 Main fuel tank filler
7 Intercooler filler
8 Cowling panels
9 Main coolant filler
10 Electrical connections, ballast weights and tail-wheel unit
11 Tailwheel, shock absorber strut (port and starboard)
12 Ground socket, electrical
13 Oil tank filler
14 Starter socket
15 Electrical connections
16 Picketing tunnels
17 Guns and ammunition boxes
18 Electrical connections, wheel bay
19 Pipe connections
20 Coolant vent cock
21 Electrical connections
22 Guns and ammunition boxes
23 Browning guns
24 Pressure head (port only)
25 Flap operating gear
26 Radiator pipe connections
27 Coolant pipe connections
28 Fuel drain cock.
29 Aileron cable drum
30 Radiator mounting
31 Flap jack
32 Aileron cable pulley
33 Aerial mounting (starboard only)
34 Aileron control lever
35 Aileron hinges





UNDERSIDE VIEW

8. On completion of the Annual Servicing the aircraft is given a full air test. If this is satisfactory, the engine cowlings are removed and all pipes and hoses are retightened. The aircraft is then deemed airworthy. Should the air test reveal any faults, this process will be repeated following remedial work.

To check items in the lower part of the cockpit during an Annual Servicing or to clear a snag, the pilot's seat will be removed. Working in the lower cockpit area is usually an uncomfortable business, however. Space is severely restricted and the cockpit has no floor as such, merely a couple of small boards on which the pilot rests his feet. The technician has a small area in which to squat down on the cockpit frames, taking care not to kick or place weight on any of the fragile items there. Then he or she must manoeuvre into position to carry out the required task. Usually, by the end of the job, the technician is nursing bruised knees and perhaps a couple of aching joints as well.

Item 4 of the Annual Servicing schedule calls for the flying control cables to be removed and examined for fraying and general wear and tear. That sounds simple enough, doesn't it? The trouble is that most of these cables are

BELOW: Line-up of BBMF Spitfires dismantled for the winter inspection in November 2006. In the foreground is Mark XIX PM631. *(Crown Copyright)*

located inside the rear fuselage. To reach them a technician needs to enter the fuselage via the 2ft-square hatch situated just forward of the tail. That entry is decidedly difficult for anyone who is, shall we say, a bit chunky. And even those of a slender disposition find the inside of a Spitfire rear fuselage a claustrophobic place with little room to manoeuvre.

Whenever an aircraft's control systems, such as the flying controls, have to be disconnected and then replaced, RAF servicing policy requires that a senior NCO *not* involved in the work must carry out an independent check. That provides a fresh pair of eyes to ensure that everything has been replaced correctly and the control surfaces move freely over the correct range.

Minor Servicing

This is carried out every 280 flying hours or four years, whichever comes first. It takes the same amount of time as the Annual Servicing, and requires the same number of technicians. This servicing includes a more thorough inspection of structurally significant items, for example the rear wing attachment brackets, the Frame 5 spar booms, and the engine bearer attachment lugs. These items are visually inspected, in some cases using a very small camera probe to see into enclosed areas.

All the checks in the Annual Servicing are carried out, but certain areas are examined more thoroughly. Also the fuel tanks are removed and examined, allowing examination of the frames beneath them.

Major Servicing

This servicing is carried out after 560 flying hours or eight years, whichever comes first. It is always undertaken by an outside contractor. If an aircraft requires a Major Servicing, the contract is put out to tender early in the year. Then, at the end of the air display season, the successful company takes delivery of the aircraft. Although the BBMF has the equipment and facilities to carry out a Major Servicing, the unit lacks the necessary personnel. Moreover, it is considered beneficial if the work takes place outside the unit so that the aircraft can be examined by fresh pairs of eyes. The work includes the following:

1. The aircraft is stripped of paint down to the bare metal, to allow a closer inspection of the structure. This servicing provides an opportunity to change the aircraft's markings when it is repainted.
2. The engine is removed and the engine bearers are X-rayed by a specialist team, who check for internal corrosion and cracking.
3. The wing spars, the fuselage and the longerons are X-rayed.
4. The tail fin is removed, as are all the flying control surfaces. In the case of the elevators and rudder, the fabric covering is removed to allow a close inspection of the structure. Afterwards the fabric is replaced using new Irish linen.
5. Major components such as the radiators, the oil cooler, the coolant header tank and the fuel tanks are removed for bay servicing. This includes pressure testing for leaks, and flushing to remove debris. Repairs are then carried out as required.
6. The undercarriage and all the hydraulic components are removed for bay servicing and checked for leaks by pressurising the component. Oil seals are replaced as required.
7. The components of the pneumatic system are removed for bay servicing.
8. The aircraft is weighed before a flight test is carried out, to ensure the centre-of-gravity is within the laid-down limits. This is done because when an aircraft is repainted it can affect the weight and therefore the centre-of-gravity setting.

Keeping records

The Royal Air Force uses the F700 system, which logs the aircraft's flying hours and records any faults (snags). The record of the flying hours and the log of faults is kept as long as the aircraft is still in service, for example Spitfire Mark VB AB910 has records dating back to 1943.
Private owners will run a similar log system, as the CAA (Civil Aviation Authority) requires the necessary paperwork in order to issue the permit to fly.

Preserving a Spitfire

Most new Spitfire owners are all too keen to fly their acquisition as soon possible. However, there are a few people who regard it as a serious financial investment, to be kept in long-term storage while inflation and rarity increase its value. Yet, like a pretty girl, a Spitfire does not take kindly to being ignored. If the aircraft is to be stored for any length of time it first needs to undergo a comprehensive inhibiting process, to preserve it until it returns to the air.

First it is ground-run to get the engine hot. Then the engine is shut down, the aircraft is pushed into a hangar, and the oil, coolant and fuel systems are all drained. The spark plugs are removed, and waxing oil is sprayed into each cylinder through the spark plug hole to coat the top of the piston and the cylinder walls. Then the spark plugs are replaced. More oil is sprayed into the exhaust system, to cover the exhaust valves.

The carburettor is filled with inhibiting oil, and the same oil is sprayed into the fuel tanks and the fuel pumps. The coolant system is filled with a liquid containing an inhibitor, and the oil system is filled with inhibiting oil. The exterior of the engine is then sprayed with WD 40 oil or Aspram inhibitor, to prevent corrosion. The propeller hub is treated in the same way. So are the undercarriage legs and any parts that are prone to condensation. If the aircraft is going to sit in a hangar for any length of time, it is jacked up and put on stands to take the weight off the wheels and the oleo legs.

The compressed air system is bled, then the air bottles are removed and their interior is sprayed with oil. The air bottles are then stored in a heated environment. The hydraulic system is left alone, as the oil fluid is a good protector in its own right.

The full process of inhibiting a Spitfire takes about a week.

ABOVE: Three types of F700 log, dating from the 1940s to the present. The F700 system is used to log an aircraft's flying hours and any faults. *(P. Blackah/Crown Copyright)*

Epilogue

M. Mafre

Now there are but a few of them left. Only a few of those myriad Spitfires which once speckled the British sky from the Orkneys to the Isle of Wight, that droned singly or in sections, squadrons or wings across the Channel, that swept at tree-top level or 30,000ft from the Pas de Calais to the southern reaches of the Elbe, that swallowed sand and harried the Afrika Korps from El Alamein to Tunisia, that duelled out of lonely Malta and chased the enemy from the Gothic Line, that patrolled the aching sunlight in the Bay of Bengal, that teetered like tipsy seamen on flimsy undercarriages aboard aircraft carriers.

A babble of tongues chattered in them. Canucks and Yanks and Britons nattered over their radios; expatriate Frenchmen, Norwegians and Poles whooped into their microphones at the sight of black-crossed fighters. Aussies and South Africans drawled at each other at vast altitudes.

Grievous things were done to the Spitfire in the name of progress. Her wings were clipped and her supercharger blades cropped for better

low-level work, and the outraged bird was dubbed the 'clipped and cropped Spitty'. They added blades to her propeller so that in the end she actually had two sets, one rotating against the other. Lumbering cannons poked out of wings designed to carry machine guns. They put a hook on her tail and called her a sea bird. Once, be it known, she slung beer kegs on her bomb racks and ferried cheer to the Normandy beachhead.

Today a vintage group of fighter pilots recall her peculiar whistling call as she arched across the sky. Nostalgia brings back the sound of her Merlin engine muttering in the misty half-light of a hundred airfields, as crewmen warmed them up at dawn in readiness. Some men who probably feel they live on borrowed time still wonder how her stout iron heart achieved the mechanically impossible and brought them home alive. Those who did not know her may wonder how mortal men can cherish an undying affection for her gasoline reeking camouflaged memory. And no one can tell them. *(Photo: Crown Copyright)*

Appendix 1

A representative selection of surviving Spitfires and Seafires

This appendix gives the life histories of a representative selection of airworthy or near airworthy Spitfires and Seafires.

Spitfire I AR213

Built by Westland at Yeovil, it was delivered to No 57 Operational Training Unit in July 1941. Transferred to 53 OTU in February 1943, where one of those who flew it was the RAF fighter ace James 'Ginger' Lacey. After a lengthy spell in storage it was sold to Allen Wheeler in March 1947, but it remained in storage until 1967, when it was returned to flying condition and took part in the film *The Battle of Britain*. In 1978 it was sold to Patrick Lindsay. Following Lindsay's death in 1986 it was sold to Victor Gauntlett at Personal Plane Services Ltd at Wycombe Air Park, Booker. Gauntlett died in 2003, and at the time of writing the Spitfire is still at PPS in the process of a major refurbishment.

Spitfire II P7350

The oldest surviving airworthy Spitfire, this aircraft was built at Castle Bromwich in 1940. Early in September, as the Battle of Britain neared its climax, this aircraft was delivered to No 266 Squadron. A few days later it transferred to No 603 Squadron. During a combat with Bf 109s in October 1940 it suffered damage and was forced to crash land (the repaired bullet holes on its port wing are still visible). It went to No 1 Civilian Repair Unit for repair, and on completion it was issued to No 616 Squadron in March 1941. The following month it moved to No 64 Squadron. In April 1942 it went to the Central Gunnery School at Sutton Bridge. In February 1943 it moved to No 57 Operational Training Unit. In July 1944 it went into storage, before being struck off charge and sold to John Dale & Sons as scrap. On seeing the aircraft's documentation, which revealed its distinguished past, the company presented it to RAF Colerne, where it sat in the station's museum hangar until 1967. It was then brought to flying condition for the film *The Battle of Britain*. In October 1968, the filming complete, P7350 was passed to the RAF's Historic Aircraft Flight. In 1973 the unit became the Battle of Britain Memorial Flight, and P7350 still flies with it.

Spitfire V AB910

Built at Castle Bromwich in 1941, this aircraft was delivered to No 222 Squadron in August. Subsequently it operated with Nos 130, 133 (Eagle), 242, 416 (RCAF) and 402 (RCAF) Squadrons. Later it served with No 53 Operational Training Unit at Hibaldstow before going into storage in May 1945. In July 1947 Group Captain Allen Wheeler purchased the aircraft and used it mainly for racing. In 1959 he sold it to Vickers-Armstrong Ltd, who presented it to the RAF's Historical Aircraft Flight in 1965. It appeared in the film *The Battle of Britain* and currently flies with the BBMF.

Spitfire V AR 501

Built by Westland at Yeovil, it was delivered to No 310 (Czech) Squadron in July 1942. Later it saw front-line service with Nos 504, 312 (Czech) and 442 (Canadian) Squadrons. Then it served with Operational Training Units until it suffered damage in an accident in September 1944. After repair it went to the Central Gunnery School in April 1945, then into storage. In 1946 Loughborough College acquired the aircraft for use as an instructional airframe. In 1961 it joined the Shuttleworth Collection and, restored to flying condition, it took part in the film *The Battle of Britain*. After a further spell in storage it underwent a lengthy rebuild, and next flew in June 1975. At the time of writing it remains with the Shuttleworth Collection, but is undergoing a major overhaul.

Spitfire V AR614

Built at Westland, Yeovil, this aircraft was delivered to No 312 (Czech) Squadron in September 1942. After suffering battle damage in May 1943, it underwent repair at Air Service Training Ltd. It went on to serve with Nos 610, 130 and 222 Squadrons, before going to No 53 Operational Training unit in September 1944. In July 1945 it went to RAF St Athan as an instructional airframe, before serving as a gate guardian at RAF stations Padgate, West Kirby and Bridgnorth. In 1963 it was sold to the Air Museum of Calgary, then on to Don Campbell of Kapuskasing, Ontario, to begin work to restore it to flying condition. In October 1992 it returned to Great Britain and went to the Old Flying Machine Company for further restoration work. In May 1994 Sir Tim Wallis and the Alpine Fighter Collection of New Zealand acquired the aircraft. Historic Flying Ltd finalised its restoration and it made its first post-restoration flight in October 1996. In 2002 this Spitfire was acquired by the Flying Heritage Collection in Seattle, USA, where it currently resides.

Spitfire V BM597

Built at Castle Bromwich, this aircraft was delivered to No 315 (Polish) Squadron in May 1942. Four months later it moved to fellow Polish unit No 317 Squadron. In February 1943 it incurred Category B damage in a landing accident. After repair it went into storage, then to No 58 Operational Training Unit in April 1945. In October 1945 it became an instructional airframe at RAF St Athan. Next came spells as gate guardian at RAF stations at Hednesford, Bridgnorth and Church Fenton. During production of the film *The Battle of Britain* it served as the master for the fibreglass replica Spitfires used during the movie's explosive combat scenes. Afterwards it returned to duty as gate guardian at RAF Church Fenton, then moved to RAF Linton on Ouse. In May 1989 it was acquired by the Tim Routsis organisation

BELOW: Spitfire Mark V BM597, currently owned by the Historic Aircraft Collection, in the Aircraft Restoration Company (ARCo) hangar at Duxford. *(Alfred Price Collection)*

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LEFT: Spitfire Mark V EP120 currently belongs to The Fighter Collection based at Duxford. *(Peter R. Arnold Collection)*

Historic Flying Ltd. After restoration it was sold to the Historic Aircraft Collection of Jersey, and it is still with that organisation based at Duxford.

Spitfire V EP120

Built at Castle Bromwich, it was delivered to No 501 Squadron in June 1942. Later it served with Nos 19 and 402 Squadrons. Credited with seven aerial victories between August 1942 and November 1943, it is probably the top-scoring surviving Spitfire in an airworthy condition. Following a flying accident it returned to Castle Bromwich for repairs, then went into storage. In June 1945 it became an instructional airframe at RAF St Athan, before serving as a gate guardian at RAF Hednesford, RAF Wilmslow, RAF Bircham Newton and RAF Boulmer. In 1968 it took part in the film *The Battle of Britain*, in a non-flying role. It then returned to being a gate guardian, serving at RAF Wattisham until 1989. In 1991 it went to Historic Flying Ltd for restoration. It next flew in September 1995 and went to The Fighter Collection at Duxford, where it remains at the time of writing.

Spitfire VIII MT719

Built at Vickers, Southampton, it was delivered to No 9 Maintenance Unit at Cosford in June 1944. Shipped to India, it went to No 17 Squadron at Vavuyuina the following September, and flew several operational missions over Burma. After the war it was sold to the Indian Air Force, but little is known of its career in that service. In the spring of 1978 it was acquired by the Haydon-Baillie brothers, Ormond and Wensley, and brought back to the United Kingdom. In 1979 it was sold on to Franco Actis in Italy, who shipped it to Turin. Following a lengthy restoration, it next flew in October 1982. It is currently owned by Jim Cavanaugh at the Cavanaugh Flight Museum at Addison, Texas.

Spitfire VIII MV154

Built at Vickers, Southampton, in 1944, it was delivered to No 6 Maintenance Unit in September 1944. Shipped to Sydney, Australia, it arrived the following November. It then went into storage until May 1948, when the Royal Australian Air Force officially wrote it off charge. In December 1948 it went to the School of

RIGHT: Spitfire Mark IX MH367 modified as a two-seater with the Grace-Melton canopy conversion. It is seen here in the colours of the USAAF 4th Fighter Squadron, which flew Spitfires from Tunisia in 1943. *(Harry Stenger)*

Aircraft Construction at Sydney, where it was used for systems testing. From 1961 it had a succession of private owners, until Robert Lamplough purchased it and brought it to Great Britain for restoration to flying condition in 1979. It made its first post-restoration flight in May 1994. At the time of writing the aircraft is airworthy and based at Bristol-Filton.

Spitfire VIII MV239

Built at Vickers, Southampton, it was delivered to No 6 Maintenance Unit in March 1945. It was shipped to Sydney, Australia, and arrived the following June. It went into storage until 1949, when it was struck off charge and given to Sydney Technical College for use as an instructional airframe. From 1961 it passed through a succession of private hands before being loaned to the Camden Museum of Aviation in New South Wales, where it was restored to ground-running condition. Acquired by Col Pay in 1983, it underwent a major overhaul and made its first post-restoration flight in December 1985. At the time of writing it is owned by David Lowy at the Temora Aviation Museum in New South Wales.

Spitfire IX MH367

Built at Castle Bromwich, this aircraft was issued to No 65 Squadron at Kingsnorth in August 1943. It suffered damage in action on 9 October and following repairs it went to No 229 Squadron the following December, then to No 312 Squadron in September 1944. After a spell in storage it went to the Empire Flying School in April 1947 and suffered Category B damage in an undercarriage collapse in July 1948. It was struck off RAF charge the following month. Some years later dilapidated parts of the airframe were found during a clear-out of a scrapyard in Wiltshire. Dick Melton Aviation, the engineering offshoot of Charles Church Spitfires, embarked on the construction of a scratch-built two-seat trainer in 1991. Following Church's death in 1989, his estate disposed of some of his holdings of Spitfire parts. In a separate move, the Jetcap Corporation of Florida acquired the incomplete trainer project. Peter Godfrey was keen to purchase and advance the project but was concerned about the lack of a verifiable RAF serial identity for the rebuild. So he bought the remains of MH367 and commissioned Harry Stenger at Bartow, Florida, to incorporate the usable parts of it in the trainer project. He also asked that the aircraft be modified with the Grace-Melton canopy conversion.

MH367 made its first post-restoration flight in September 2006, painted in the colours of a Spitfire of the USAAF 4th Fighter Squadron, which flew these aircraft on operations from La Sebala, Tunisia, in June 1943. It is currently based at Bartow, Florida.

Spitfire IX MH434

Built at Castle Bromwich, it was delivered to No 222 Squadron in August 1943. It was flown in combat by the South African Flight Lieutenant Henry Lardner-Burke, who was credited with the destruction of two Fw 190s and a share in a Bf 109. In 1944 it served with No 350 Squadron for a time, then returned to No 222 Squadron. After a spell in storage it was bought by the Royal Netherlands Air Force. In 1947 it went with No 322 Squadron to Semarang, Java, where it fought during the Indonesian war of independence. Damaged in a crash landing, it was brought back to Holland and repaired, and went into storage. It then transferred to the Belgian Air Force, where it served at the Advanced Pilot School at Koksijde.

In March 1956 it was bought by the COGEA organisation for use as a target tug, and went on the Belgian civil register as OO-ARA. There it remained for the next seven years, until airline pilot Tim Davies purchased it. He brought it back to Great Britain, where it had a full overhaul and was restored to flying condition. It

ABOVE: Spitfire Mark IX MH434, one of the best-known restored Spitfires. This photograph shows the aircraft in March 1944, when it was operated by No 222 Squadron based at Hornchurch. *(Bill Burge)*

then took part in the films *Operation Crossbow* and *The Battle of Britain*. Later it was bought by Sir Adrian Swire, Chairman of Cathay Pacific Airways, and took part in more films, including *A Bridge Too Far*. In 1983 it was bought by Ray Hanna for Nalfire Aviation Ltd consortium before going to the Old Flying Machine Company at Duxford, where it currently resides.

Spitfire IX MJ627

Built at Castle Bromwich, this aircraft was delivered to No 9 Maintenance Unit in December 1943 and held in storage. It entered service with No 441 Squadron in September 1944 and suffered damage in an accident in March 1945. After repair it remained in storage until July 1950, when it was sold to Vickers Ltd. The company converted it into a two-seat trainer, and sold it on to the Irish Air Corps in June 1951. After retirement in 1960 it served as an instructional airframe, before going to Film Aviation Services late in 1963. Maurice Bayliss bought the aircraft in 1976 and he still owns it. The Spitfire made its first post-restoration flight in November 1993 and it is still in an airworthy condition at East Kirby airfield.

Spitfire IX MJ730

Built at Castle Bromwich, it was delivered to No 33 Maintenance Unit at Lyneham in December 1943. It was shipped to Casablanca and arrived there in February 1944. Served for a time with No 249 Squadron. In June 1946 it was sold to the Italian Air Force, then in 1950 it was resold to the Israeli AF. Found in a derelict condition in 1976, it was acquired by Robert Lamplough and brought to Great Britain in 1979. Restored by Trent Aero, it made its next flight in November 1988. It was then sold to Jerry Yagen at the Tidewater Tech Fighter Factory, Suffolk, Virginia, and still resides there.

Spitfire IX MK356

Built at Castle Bromwich, this aircraft was issued to No 443 (Canadian) Squadron in March 1944. It flew extensively during the air operations in preparation for, and following, the Normandy invasion in June. In August, following damage sustained in a wheels-up landing, it moved to No 83 Group Support Unit for repairs and then went into storage. In October 1945 it became an instructional airframe at RAF Halton. In 1951 it went to RAF Hawkinge, where it

ABOVE: Spitfire IX MJ730 in the condition it was found at the Kabri Kibbutz in Israel in 1976. Following restoration, it next flew in October 1988. *(Peter R. Arnold Collection)*

served as a gate guardian for the next decade. In 1961 it underwent restoration work at RAF Bicester, then went to RAF Locking, again as a gate guardian. It served in a non-flying role in the film *The Battle of Britain*. After a spell in storage at RAF Henlow, in 1969 it joined the RAF Museum reserve collection held at RAF St Athan. Over the next eight years it underwent restoration and next flew in November 1997. It then went to the BBMF, where it is currently presented as a clipped wing Spitfire F Mk IX bearing the '2I' code letters of its original unit, No 443 Squadron.

Spitfire IX MK732

Built at Castle Bromwich, it was delivered to No 485 Squadron in March 1944. Flew in support of the D-Day invasion of France on 6 June, during which it was credited with a share of a Ju 88 destroyed. Damaged in action early in September 1944 it was repaired, only to suffer more serious damage in an accident at the end of the month. After repair at a Civilian Repair Unit it went into storage. In June 1948 it was sold to the Royal Netherlands Air Force, and served at the Fighter School at Twente. Following damage in an accident in November 1949, it went to Fokker for repairs, then served with No 322 Squadron from April 1951 to September 1953. In 1969 it was brought back to Great Britain to provide spares for BBMF Spitfires. In March 1984 its remains went back to Holland but in 1991 it returned to Great Britain and work began to restore it to a flying configuration. Its first post-restoration flight took place in July 1993, and at the time of writing it serves with the Royal Netherlands Air Force Historic Flight based at Gilze Rijen, Holland.

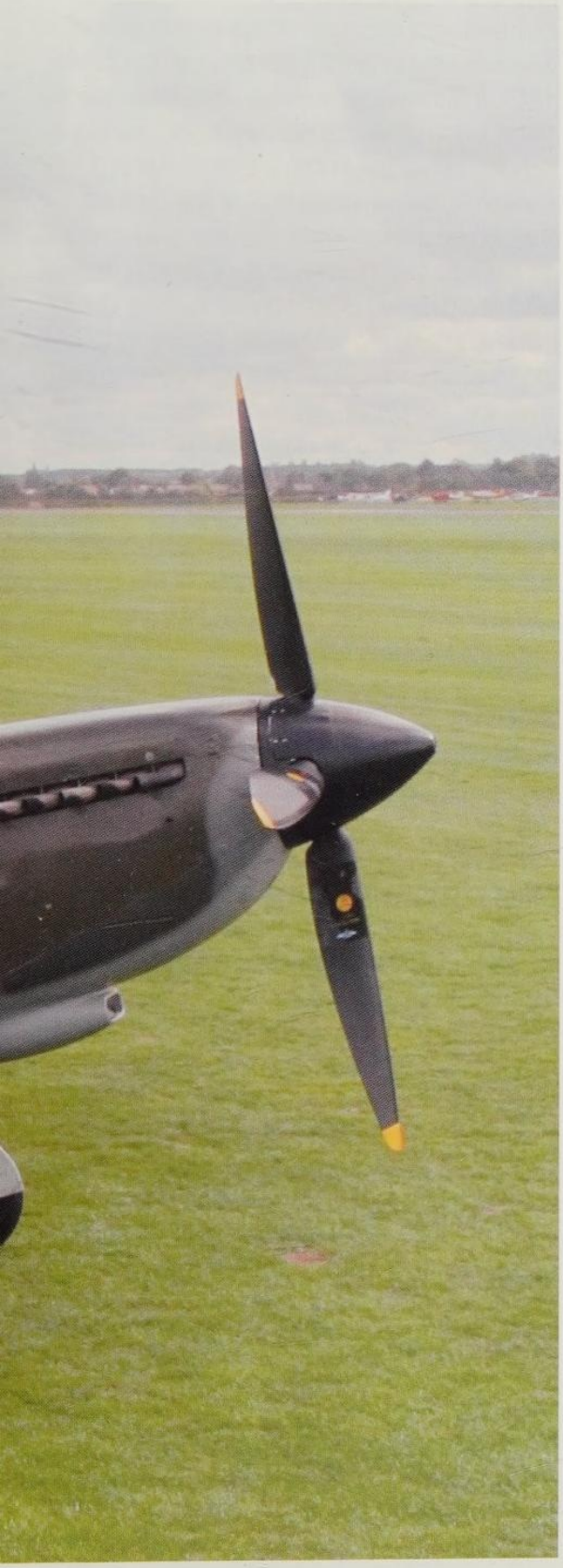
Spitfire IX MK 912

Built at Castle Bromwich, it was issued to No 312 (Czech) Squadron in June 1944. Little is known of its subsequent career, but in April 1945 it went into storage at No 33 Maintenance Unit, Lyneham. In July 1946 it was sold to the Royal Netherlands Air Force, and served with No 322 Squadron in Java during the Indonesian war of independence. Following the end of that war in 1949 it was shipped back to Holland, and in 1950 it was sold to the Belgian Air Force. After overhaul by the Fokker company it served at the Advanced Flying School at Brustem,

then at the Fighter School at Coxyde. In 1955 it was set up on a concrete plinth at the entrance to the Belgian Air Force Technical School at Saffraenberg, and remained there for the next 30 years. It was then shipped to Great Britain and went to Historic Flying Ltd for restoration to flying condition. The work completed, in 2003 Ed Russell bought it for a reported £1 million. The aircraft is currently based at Niagara, Canada.

Spitfire IX ML407

Built at Castle Bromwich, ML407 was delivered to No 485 Squadron in April 1944. The following December it was assigned to 145 Wing, before going to No 341 (Alsace) Squadron in January 1945. In the weeks to follow it served with Nos 308, 349, 485, 345, and 332 Squadrons, before returning to Great Britain and going into storage in September 1945. Bought by Vickers Ltd in July 1950, it was converted into a two-seat Mark IX trainer and sold to the Irish Air Corps in June 1951. In 1960 it was retired and placed in storage. In March 1968 it was sold, and after passing through a succession of new owners it was bought by Nick Grace in August 1979. After a rebuild in 1985 it was fitted out as a two-seater with the unusual Grace-Melton canopy conversion. Following the death of Nick Grace in a road accident in October 1988, ML407 passed to his widow, Carolyn, who flies it regularly at air shows. Currently the aircraft resides at Duxford.



Spitfire IX ML417

Built at Castle Bromwich in 1944, it was delivered to No 443 (RCAF) Squadron on 2 June. It went into action over France on D-Day and at the end of the month was operating from the forward landing ground at St Croix-sur-Mer, Normandy. It was credited with two Bf 109s destroyed and one damaged, and an Fw 190 damaged. The aircraft subsequently served with Nos 401, 441 and 442 Squadrons, then went into storage in August 1945. In October 1946 Vickers-Armstrong Ltd bought it back and converted it into a two-seat trainer for the Indian Air Force. In October 1948 it entered that service as HS543. In 1967 it went into the IAF Museum at Palam, where US Senator Norman Garr purchased it in April 1971 and brought it to the USA. It remained in storage at New Orleans until November 1972, when Stephen Grey purchased it and brought it back to Great Britain. During restoration by Personal Plane Services at Booker it was returned to its original, single-seat, configuration. It next flew in February 1984, and spent time with The Fighter Collection at Duxford. In 1999, while parked at Le Touquet, it suffered an undercarriage collapse. It was repaired and underwent a major overhaul at Duxford, and next flew in June 2001. It was then sold to Tom Friedkin, who shipped it back to the USA. It currently flies from Chino, California.

Spitfire IX, PT462

Built at Castle Bromwich, it was delivered to No 39 Maintenance Unit in July 1944. It was

LEFT: Spitfire IX ML407, was later modified into a two-seater with the unusual Grace-Melton canopy conversion. The aircraft is pictured at the head of the line-up at Duxford during the air display on 3 September 2006. The aircraft is currently owned by Carolyn Grace *(Peter R. Arnold)*

shipped to the Mediterranean Allied Air Force and served with No 253 Squadron in 1945. In June 1947 it transferred to the Italian Air Force, and in 1952 it was sold to the Israeli Air Force. In 1983 Robert Lamplough found the aircraft in a dilapidated state at a kibbutz in Israel, and brought it back to Great Britain. Charles Church bought the parts in 1985, and restored it to flying condition and converted it to a Mark IX two-seat Spitfire Trainer. It first flew after its restoration in July 1987. After Charles Church died in a flying accident it went to the USA and was bought by Jetcap Aviation, Florida. It did not remain there long, however, for Anthony Hodgson purchased it and brought it back to Great Britain for the Aircraft Restoration Company at Duxford. It currently flies with the Dragon Spitfire Flight, from a private airstrip in North Wales.

Spitfire IX TE308

Built at Castle Bromwich in June 1945, this aircraft's RAF record card appears to have gone missing. It is known that it was sold back to Vickers Ltd in July 1950, and converted to a two-seat trainer configuration. In July 1951 it went to the Irish Air Corps, and remained there until it was struck off charge in 1961. After taking part in the film *The Battle of Britain* in 1968 it was bought by Don Plumb, who took it to Ontario, Canada. Later the rear cockpit was faired over to make the aircraft look like a single-seat Spitfire. It was then bought by the Owl's Head Transportation Museum, at Rockland, Maine, USA, in 1975. After passing through several hands it is currently owned by Bill Greenwood at Aspen airport, Colorado.

Spitfire XIV MV293

Built by Vickers-Armstrong, Keevil, it left for India in August 1945 and arrived at Karachi in October. Too late for the war, it went into storage until it was bought by the Indian Air Force in December 1947. It served for a time as an instructional airframe at the IAF Technical College at Jalahalli. Acquired by Warbirds of Great Britain, it was brought back to the UK, where it was purchased by The Fighter Collection, its current operator. Its first post-restoration flight was in August 1992. At the time of writing it is based at Duxford, and is painted with the serial MV268 and JEJ initials of the Spitfire XIV that 'Johnnie' Johnson flew in action during the spring of 1945.

Spitfire XVI TE184

Built at Castle Bromwich in 1945, this aircraft was delivered to No 9 Maintenance Unit in May 1945. It remained in storage until September 1948, when it went to No 203 Advanced Flying School. In February 1950 it went to No 607 Squadron, then in November to the Central Gunnery School. In February 1951 it went to No 64 Reserve Centre, then in the following year to No 1855 (Royton) Squadron Air Training Corps. It subsequently moved to RAF Finningley to join the museum collection there. After restoration it went to the Ulster Folk and Transport Museum, then into storage until Nick Grace bought it in 1986. Registered to Myrick Aviation Services, it made its first flight after restoration in November 1990. Sold to Alain de Cadenet in 1995, it is currently owned by Paul Andrews and is undergoing restoration at Personal Plane Services, Booker.

Spitfire XIX PS853

Built at Supermarine, Southampton, this aircraft was delivered to the Central Reconnaissance Unit, RAF Benson, in January 1945. A few weeks later it transferred to No 16 Squadron, a 2nd Tactical Air Force reconnaissance unit based at Brussels/Melsbroek and later at Eindhoven. The aircraft flew a total of nine operational sorties, several of them as part of Operation Crossbow to photograph areas suspected to contain V.1 or V.2 launching sites. After the end of the war No 16 Squadron moved to Celle in Germany as part of the British occupation force.

PS853 returned to Great Britain in March 1946 and went into storage at High Ercall in Shropshire. In January 1949, apparently as it was being prepared for use, the aircraft suffered Category B damage in a flying accident and returned to the makers for repairs.

Its next assignment was to the Meteorological Flight, operated by Short Brothers and Harland Flying Services Division for the government. To prepare it for this new role, PS853 went to No 9 Maintenance Unit

at Cosford to have its cameras and other reconnaissance equipment removed, and the meteorological recording systems installed. The aircraft began operations in the THUM (Temperature and Humidity of the Upper air Masses) role early in 1951, one of several PR XIXs conducting the measuring flights from Hooton Park. In April 1952 the unit moved to Woodvale, and continued operations as before.

In June 1957 the Flight re-equipped with Mosquitos, and PS853 made its final THUM flight on the 10th. On 14 June the three PR XIXs flew to Biggin Hill, to join the RAF's new Historic Aircraft Flight. In March 1958 the HAF moved to North Weald, then in the following month to West Raynham, where PS853 was reduced to non-flying status.

The aircraft remained there until 1961, when it was decided to restore it to flying condition. PS853 went to No 19 Maintenance Unit for refurbishment, then returned to West Raynham. It remained there until April 1964, when it returned to the Historic Aircraft Flight.

PS853 remained with the Flight for the next three decades. Then, in 1994, it was sold to defray the cost of rebuilding the Flight's sole Hurricane, which had been seriously damaged in a crash and subsequent fire. The sale was a drawn-out process. Eventually Euan English purchased PS853, but soon afterwards he was killed in a flying accident in another aircraft. His widow put the Spitfire up for auction, and in September 1994 Rolls-Royce plc became the new owner. The company maintains the aircraft in a flying condition at Bristol-Filton at the present time.

Spitfire XIX PS915

Built at Supermarine, Southampton, it was delivered to RAF Benson in April 1945 and served with No 541 Squadron. In July 1948 it went to No 2 Squadron at Wunsdorf in Germany. Following a flying accident it was repaired, and after a spell in storage it was issued to the Meteorological Flight at Woodvale in June 1954. When that unit disbanded in June 1957, the aircraft passed to the Historic Aircraft Flight at Biggin Hill. Soon afterwards it was grounded and became a gate guardian, first at RAF West Malling, then at Leuchars, and later at Brawdy. From 1984 to 1986 it was at British Aerospace at Warton for restoration to flying condition. It resumed flying in December 1986. In March 1987 it passed to the BBMF, March, where it currently serves.

Seafire XVII SX336

Built by Westland Aircraft at Yeovil, SX336 made its first flight in May 1946. In August it was delivered to the Royal Navy's Aircraft Holding Unit at Abbotsinch. Little is known about its subsequent career in the Fleet Air Arm, though it was recorded as being at Naval Air Station Bramcote in 1953, and NAS Stretton in 1955. Some time later it was sold to the British Aluminium company at Warrington for scrap.

There the aircraft might have disappeared for ever, had not the Warrington scrapyard of Joseph Brierley and Son acquired the battered remains and decided to hold on to them until a suitable purchaser turned up. Some years later one did, in the shape of Spitfire and Seafire historian and collector Peter Arnold. The latter had received a tip-off that major parts of a couple of Seafire XVIIs, SX336 and sister aircraft SX300, were in a poor but recognisable condition at the yard. A swift visit in July 1973, and the handing over of £170 plus VAT, secured for Peter the remains of both aircraft.

Next, in a barter deal, SX336 – the better of the two Seafires – passed to Neville Franklin. The next 15 years in the story had an air of 'pass the parcel' about it, as the collection of parts passed from owner to owner, acquiring additional items in the process. In the process Craig Charleston and Peter Wood were heavily involved in the restoration. Then, in June 2001, the collection of parts went to the Kennet workshop at Cranfield airfield where, finally, the restoration was completed. SX336 made its first post-restoration flight in May 2006, to become the only airworthy Seafire remaining in Britain.

Seafire 47 VP441

At the time of writing this is the youngest Spitfire or Seafire to survive in an airworthy condition. VP441 made its maiden flight from South Marston in November 1947. In January 1948 the aircraft was issued to No 804 Squadron, then in the process of converting from Seafire XVs to Seafire 47s at Royal Naval Air Station

RIGHT: Doing things in style: Jim Smith's Seafire 47 lined up on the runway of his private airfield at Crystal Lakes, Montana. In addition to the Seafire he has some 20 other aircraft in his Warbird collection. *(Peter R. Arnold)*

Ford in Sussex. In August the Squadron embarked on the light fleet carrier HMS *Ocean*, which then sailed for the Mediterranean. While in that area the airfield at Hal Far, Malta, served as the unit's shore base. It also spent a short time embarked on HMS *Triumph*. In March 1949 VP441 appears to have suffered damage, for it left the Squadron and went to the aircraft holding unit at Ford, then in May it went to the aircraft repair facility at Fleetlands. From there it was sent to the Fleet Air Arm training school at Manadon as a ground instructional airframe. The aircraft served in that role until it was struck off charge in January 1954.

The next stop for VP441 was the Air Training Corps squadron at Saltash near Plymouth, where it sat in the open outside the headquarters. There it remained for a decade, deteriorating steadily, until it was acquired by the Historic Aircraft Preservation Society. The Society and the Air Engineering Department at RNAS Culdrose restored the aircraft to display condition, and it was shown at the station's Navy Day in 1965. Thereafter it moved to the HAPS base at Squires Gate near Blackpool, but its stay at the new venue was not a success. By 1972 the HAPS was in financial difficulties, which led to a high court injunction from the airfield's owners to secure unpaid rent. The HAPS collection of aircraft went under the auctioneer's hammer, and VP441 went to Personal Plane Services at Booker for storage until its new owner decided what to do next.

In 1975 the Seafire was bought by John Stokes and the aircraft was shipped to Texas. There it remained in storage for a further couple of decades, until Jim Smith bought it to add to his personal collection of more than a score of Warbird aircraft. The new owner had amassed a large fortune producing clever design solutions to engineering problems, and when Ezell Aviation at Breckenridge, Texas, carried out the restoration work he played an active part. The aircraft was restored with many of its original systems working, including its hydraulically-powered wing folding mechanism. The only remaining Seafire 47 in the world made its first post-restoration flight in April 2004, with an ex-Shackleton Griffon 58 engine driving the authentic six-blade contra-rotating propeller.

Appendix 2

How many airworthy Spitfires are there now, worldwide?

The authors acknowledge the valuable assistance of Peter Arnold in the preparation of this chapter and for his permission to include the census of Spitfires that follows.

So, how many airworthy Spitfires *are* there now, worldwide? That question is difficult to answer with accuracy. Everything hinges on how one defines the word 'airworthy'. Does it include only those Spitfires that could be wheeled out of their hangar tomorrow morning, start their engine and take off? In that case the answer to the question is 'somewhere around 20', though the exact number will fluctuate from day to day. Much depends on the season of the year, for that would have to exclude aircraft in the process of undergoing their annual winter scheduled maintenance and repair. It also excludes previously airworthy Spitfires undergoing rebuilds, and aircraft that have suffered damage but are being repaired for flight. Then there are aircraft that were flying until recently, but whose owners have decided to put them in a museum or in storage for a 'rest'.

Rather than ask a question that cannot be answered with accuracy, it is more productive if the question can be rephrased. The low point for the number of airworthy Spitfires was during the mid 1960s when only ten such machines existed in the world. Then in 1969 came the film *The Battle of Britain*, which sparked off an interest among some very rich people around the world to own, restore and perhaps fly a Spitfire. The authors believe that the best indicator of the number of Spitfires now flyable, or potentially flyable, is to list those flown or restored to flight since that pivotal year of 1969. At the time of writing, early 2007, that number stands at 70 Spitfires and Seafires. Given the vibrancy of the present day 'Spitfire Industry', there is little doubt that this number will continue to grow in the years to come.

Of the 70 aircraft listed in the schedule that follows it is considered that 42 are fully airworthy, provided one disregards the time spent on the ground for routine maintenance. It is to be hoped that all 42, plus two or three more in the pipeline, will take to the air at some time during the 2007 display season.

	RAF	Civil Reg	Mk	Owner/Custodian	Location	Status
1	AR213	G-AIST	F. Mk I	Sheringham Aviation	Booker, UK	Under major refurbishment
2	P7350	Military	F. Mk II	MoD	Coningsby, UK	Fully airworthy
3	AB910	Military	F. Mk V	MoD	Coningsby, UK	Fully airworthy
4	AR501	G-AWII	F. Mk V	ShuttleworthTtrust	Old Warden, UK	Under major refurbishment
5	AR614	N614VC	F. Mk V	Paul Allen/FHC	Seattle, Washington, USA	Fully airworthy
6	BM597	G-MKVB	F. Mk V	Guy Black/HAC	Duxford, UK	Fully airworthy
7	EE606	G-MKVC	F. Mk V	David Arnold	(Parts only)	Total write-off after crash
8	EP120	G-FVB	F. Mk V	Stephen Grey/TFC	Duxford, UK	Fully airworthy
9	JG891	G-FVC	F. Mk V	Tom Blair/Spitfire Ltd	Duxford, UK	Fully airworthy
10	MT719	N719MT	F. Mk VIII	Jim Cavanaugh/CFM	Dallas, Texas, USA	Fully airworthy
11	MT818	N58JE	TR. Mk VIII	Provenance Fighter	Murrieta, California, USA	For sale
12	MV154	G-BKMI	F. Mk VIII	Rob Lamplough	Filton, UK	Fully airworthy
13	MV239	VH-HET	F. Mk VIII	David Lowy	Temora, Australia	Fully airworthy
14	NH631	Military	F. Mk VIII	Indian AF Historical Flight	Palam, India	Flying suspended
15	MA793	N930LB	F. Mk IX	TAM Museum	Sao Carlos, Brazil	Museum display
16	MH367	N367MH	TR. Mk IX	Peter Godfrey	Bartow, Florida, USA	Fully airworthy
17	MH434	G-ASJV	F. Mk IX	Old Flying Machine Co	Duxford, UK	Fully airworthy
18	MH415	N415MH	F. Mk IX	Wilson Edwards	Big Spring, Texas, USA	Long-term storage

	RAF	Civil Reg	Mk	Owner/Custodian	Location	Status
19	MJ627	G-BMSB	TR. Mk IX	Maurice Bayliss	East Kirkby, UK	Fully airworthy
20	MJ730	N730MJ	F. Mk IX	Jerry Yagen	Suffolk, Virginia, USA	Fully airworthy
21	MJ772	N8R	TR. Mk IX	Doug Champlin	Seattle, Washington, USA	Museum display
22	MK297	NXBL	F. Mk IX	-	Hamilton, Canada	Total write-off after fire
23	MK356	Military	F. Mk IX	MoD	Coningsby, UK	Fully airworthy
24	MK732	PH-OUQ	F. Mk IX	RNethAF Historical Flight	Gilze Rijen, Netherlands	Fully airworthy
25	MK912	C-FFLC	F. Mk IX	Ed Russell	Niagara, Canada	Fully airworthy
26	MK923	N521R	F. Mk IX	Craig McCaw/MoF	Seattle, Washington, USA	Museum display
27	MK959	N959RT	F. Mk IX	Raybourne Thompson	Houston, Texas, USA	Fully airworthy
28	ML407	G-FIX	TR. Mk IX	Carolyn Grace	Duxford, UK	Fully airworthy
29	ML417	N2F	F. Mk IX	Tom Freidkin	Chino, California, USA	Fully airworthy
30	NH238	G-MKIX	F. Mk IX	David Arnold	Greenham Common, UK	Long-term storage
31	PL344	N644TB	F. Mk IX	Tom Blair	Duxford, UK	Under major refurbishment
32	PT462	G-CTIX	TR. Mk IX	Anthony Hodgson	Bryn Gwyn Bach, UK	Fully airworthy
33	PV202	G-CCCA	TR. Mk IX	Karel Bos/FL	Duxford, UK	Fully airworthy
34	TA805	G-PMNF	F. Mk IX	Peter Monk	Duxford, UK	Fully airworthy
35	TE213	Military	F. Mk IX	SAAF Museum Flight	Lanseria, South Africa	Major accident – stored
36	TE308	N308WK	TR. Mk IX	Bill Greenwood	Aspen, Colorado, USA	Fully airworthy
37	TE554	Military	F. Mk IX	Israeli Air Force Museum	Beersheba, Israel	Fully airworthy
38	TE566	VH-IXT	F. Mk IX	Aviation Australia	Brisbane, Australia	Major accident – stored
39	PL965	G-MKXI	PR. Mk XI	Peter Teichman	North Weald, UK	Fully airworthy
40	PL983	G-PRXI	PR. Mk XI	Propshop/FL	Duxford, UK	Under major refurbishment
41	MV293	G-BGHB	FR. Mk XIV	Stephen Grey/TFC	Duxford, UK	Fully airworthy
42	NH749	NX749DP	FR. Mk XIV	Commemorative AF	Camarillo, California, USA	Under major refurbishment
43	NH799	ZK-XIV	FR. Mk XIV	Paul Page	Ardmore, New Zealand	Under major refurbishment
44	NH904	N114BP	FR. Mk XIV	Bob Pond	Palm Springs, California, USA	Fully airworthy
45	RM689	G-ALGT	F. Mk XIV	Rolls-Royce	Bristol, UK	Under major refurbishment
46	RN201	G-BSKP	F. Mk XIV	Tom Blair/Spitfire Ltd	Kissimmi, Florida, USA	Fully airworthy
47	SM832	N54SF	F. Mk XIV	Tom Freidkin	Chino, California, USA	Fully airworthy
48	TZ138	C-GSPT	FR. Mk XIV	Robert Jens	Vancouver, Canada	Airworthy, resting
49	RR263	Military	F. Mk XVI	Musee de l'Air	Paris, France	Museum display
50	RW382	NX382RW	F. Mk XVI	Steve Vizard	Isle of Wight, UK	Major accident – stored
51	RW386	G-BXVI	F. Mk XVI	Billt Halsab	Englesholm, Sweden	Fully airworthy
52	SL721	C-GVZB	F. Mk XVI	Mke Potter	Ottawa, Canada	Fully airworthy
53	TB863	VH-XVI	F. Mk XVI	David Lowy	Temora, Australia	Fully airworthy
54	TD248	G-OXVI	F. Mk XVI	Tom Blair/Spitfire Ltd	Duxford, UK	Fully airworthy
55	TE184	G-MXVI	F. Mk XVI	Paul Andrews	Booker, UK	Under major refurbishment
56	TE356	N356EV	F. Mk XVI	Evergreen Ventures	McMinville, Oregon, USA	Museum display
57	TE384	N384TE	F. Mk XVI	Ken McBride	Hollister, California, USA	Long-term storage
58	TE392	N97RW	F. Mk XVI	Robert Waltrip/LSFM	Galveston, Texas, USA	Fully airworthy
59	TE476	N476TE	F. Mk XVI	Kermit Weeks	Polk City, Florida, USA	Museum display
60	SM845	G-BUOS	FR. Mk XVIII	Karel Bos/FL	Duxford, UK	Fully airworthy
61	SM969	G-BRAF	F. Mk. XVIII	Stephen Grey/TFC	Duxford, UK	Under major refurbishment
62	TP280	N280TP	FR. Mk XVIII	Rudy Frasca	Urbana, Illinois, USA	Fully airworthy
63	TP298	N41702	FR. Mk XVII	Murray Gilchrist	Brisbane, Australia	Major accident – stored
64	PM631	Military	PR. Mk XIX	MoD	Coningsby, UK	Fully airworthy
65	PS853	G-RRGN	PR. Mk XIX	Rolls-Royce	Bristol, UK	Fully airworthy
66	PS890	F-AZJS	PR. Mk XIX	Cristophe Jaquard	Dijon, France	Fully airworthy
67	PS915	Military	PR. Mk XIX	MoD	Coningsby, UK	Fully airworthy
68	PK350	Military	F. Mk 22	-	Harare, Zimbabwe	Total write-off after crash
69	SX336	G-KASX	F. Mk XVII Seafire.	Tim Manna	North Weald, UK	Fully airworthy
70	VP441	N47SF	FR. Mk 47 Seafire	Jim Smith	Crystal Lakes, Montana, USA	Fully airworthy

Appendix 3

Glossary of terms

A detailed explanation of some of the terms used within this manual.

Boost The pressure of the fuel/air mixture in the induction manifold of the engine. Measured in pounds per square inch on the boost gauge in the cockpit, this indicates power level delivered by the engine.

Constant speed unit (CSU) This unit, fitted to the engine, automatically controls the engine rpm and the propeller pitch mechanism so that they operate at high efficiency over a wide range of flight conditions. The pilot sets the required engine rpm using his control lever, and a governor automatically controls the pitch of the propeller blades. Thus the aircraft flies at the most efficient value for the engine power selected and the speed of the aircraft.

Fuel Pre-war Spitfires ran on 87 octane fuel, replaced early in the war by 100 octane fuel when this became available. Thereafter higher octane fuels were sometimes used for specialised applications. For example, to give improved speed performance at low altitude to intercept V1 flying bombs, some Spitfires were fitted with highly-tuned short-lifed Merlin engines employing 150 octane fuel. The change added 30mph to the maximum speed of the Spitfire IX at low altitude, usable for a maximum of five minutes. Present-day Spitfires operate on 100 LL (100 octane low lead) fuel.

IFF See transponder.

Pitot head Pressure-measuring head, mounted under the port wing of the Spitfire, to measure the indicated airspeed.

Pre-oiler Modification to modern-day Spitfires, to reduce engine wear. System employs a small pump to circulate oil around the engine, to ensure that all parts are properly lubricated. prior to start-up.

Pressurised cabin Fitted to Spitfires Mark VI, VII, X and XIX intended to operate at high altitude, with strengthened cabin structures and cockpit canopies. In these aircraft the cabin was maintained at the equivalent pressure at 25,000ft, when the aircraft was flying at about 40,000ft. That degree of pressurisation was much less than in a modern airliner, and the pilot had still to breathe oxygen through a facemask if he was to maintain full consciousness.

Self-sealing fuel tank The lower tank of the Spitfire has a self-sealing rubberised covering. When a bullet or a shell splinter pierced the tank below the fuel level, fuel leaked out. As that fuel came into contact with the rubberised covering it set up a chemical reaction that caused the rubber to swell until it sealed off the hole.

Transponder This is a so-called secondary radar system, as distinct from a primary radar system which tracks an aircraft by bouncing radar signals off it. In the secondary radar system a ground station radiates signal, which triggers the transponder in the aircraft. The latter then radiates a coded reply. A typical application of this was the wartime IFF (identification friend or foe) system, which identified the aircraft as 'friendly' to the ground station. On modern aircraft flying in controlled airspace, there is a legal requirement for each aircraft to carry a transponder to enable ground stations to track its movements.

Vacuum system Employed to drive the gyroscopic instruments on the blind flying panel: the artificial horizon, the turn-and-slip indicator and the direction indicator.

UHF Ultra high frequency, the band 225 to 400MHz used by military aircraft for radio communications.

VHF Very high frequency in the band 118 to 136MHz, used by military and civil aircraft for radio communications.

Appendix 4

Useful contacts

Airframe Assemblies
Hangar 6S
Isle of Wight Airport
Sandown
Isle of Wight
PO36 0JP
Tel 01983 408661/404462
Produces replacement airframes.

Anglia Radiators
Unit 4
Stanley Road
Cambridge
CB5 8LB
Tel 01223 314444
Builds replacement radiators and oil coolers.

ARCO
Duxford Airfield
Cambs, CB2 4QR
Tel 01223 835313
Provides maintenance facilities for historic aircraft.

Dowty Propellers
Anson Business Park
Cheltenham Road East
Gloucester
GL2 9QN
Tel 01452 716000
Builds and refurbishes propellers.

Dunlop Tyres
40 Fort Parkway
Erdington
Birmingham
West Midlands
B24 9HL
Produces replacement tyres for Spitfires.

Hanley Smith
7 South Road
Templefields
Harlow
Essex, CM20 2AP
Tel 01279 414446
Overhauls undercarriage legs.

Historic Flying
Duxford Airfield
Cambs, CB2 4QR
Tel 01223 839455
Builds and rebuilds Spitfires.

Ormonde Aircraft Ltd
Hangar 2
Nottingham Airport
Tollerton Lane
Nottingham
NG12 4GA
Tel/Fax 01159 813343
Produces replacement airframe components.

Personal Plane Services Ltd
Wycombe Air Park
Booker
Marlow
Buckinghamshire
SL7 3DS
Tel 01494 449810
Overhauls and rebuilds aircraft.

Retro Track and Air
Upthorpe Iron Works
Upthorpe Lane
Dursley
Gloucestershire
GL11 5HP
Tel 01453 545360
Overhauls engines.

Skycraft
12 Silver Street
Litlington
Nr Royston
Herts
SG8 0QE
Tel 01763 852150
Builds and refurbishes propellers.

Smiths Industries, Aerospace
www.smiths-aerospace.com
Aircraft instruments.

Supermarine Aero Engineering Ltd
Mitchell Works
Steventon Place
Burslem
Stoke-on-Trent
Stafford
ST6 4AS
Tel 01782 811344
Machine components.

Vintage Fabrics Ltd
Mitchell Hangar
Audley End Airfield
Saffron Waldon
Essex
CB11 4LH
Tel 01799 510756
Fabric for the flying controls, rudder and elevators.

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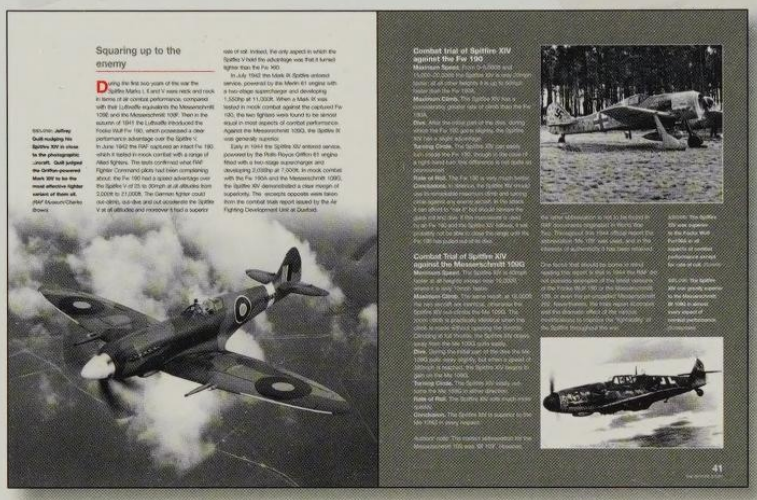
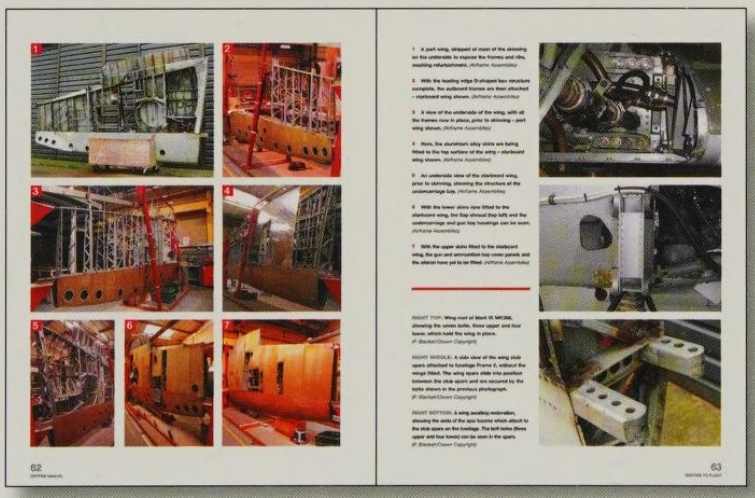

Squaring up to the enemy
Combat trial of Spitfire XIV against the Fw 190
Combat Trial of Spitfire XIV against the Messerschmitt 109Q



'crammed with superb pictures and illuminating detail' *Aeroplane*

Today the sight and sound of a Spitfire strutting its stuff is the high point of any air show. More than 22,000 of these aircraft were built, and the youngest survivor – a Seafire variant – first flew in 1947, making it 60 years old.

However, preparing for such longevity was not a consideration for those who designed and built these aircraft. During hard-fought periods of the war, a Spitfire had an average life of just a few weeks.

In the years following the war the number of airworthy Spitfires plummeted, and by the mid-1960s only eight remained in Great Britain. Then came the epic film *The Battle of Britain*, which needed all the operational Spitfires it could get to perform the aerial battle scenes. The film, released in 1969, proved a huge box office success. It also led to an explosion of interest in surviving airworthy Spitfires, and showed that almost anyone, provided he or she was wealthy enough, could own and perhaps fly a Spitfire.

This book provides a brief history of this iconic aeroplane and a fascinating behind-the-scenes insight into what is involved in restoring, flying and maintaining a Spitfire today, nearly 70 years after the first prototype flew.

Dr Alfred Price served for 15 years as an aircrew officer in the Royal Air Force, where he was a crewman on Vulcan bombers, specialising in electronic warfare and air-fighting tactics. Since leaving the service, he has been a full-time writer on aviation subjects, and is a well-respected aviation historian and an acknowledged authority on the Spitfire. He is a Fellow of the Royal Historical Society.

Paul Blackah joined the RAF in 1976 and trained as an airframe fitter. In 1993 he was posted to the Battle of Britain Memorial Flight (BBMF) and remained with that unit until he retired from full-time service in 2002. His specialised knowledge of vintage aircraft, and in particular the Spitfire, was considered so valuable to the Flight that he was taken into the RAF as a reservist, working as Airframe Specialist in the BBMF.

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